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CRASHWORTHY HELICOPTER GUNNER'S SEAT INVESTIGATION

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Current Army aircraft do not provide crashworthy gunner seats or adequate restraint systems for gunners operating pintle-mounted machine guns. Consequently, gunners improvise seats (ammunition boxes, bar stools, etc.) for use during gunner operations and also use either inadequate restraint systems or no restraint system at all while standing in aircraft doorways and sometimes on the aircraft skids.

A number of gunner seat concepts and restraint system designs were developed and evaluated against such factors as weight, cost, human factors, operational constraints, ballistic protection, etc. Based upon evaluation of these concepts, one design was selected and a seat was fabricated and installed in an aircraft and subjected to a human factors mockup evaluation using gunners with various clothing and equipment. These evaluations permitted the formulation of a practical military specification for a crashworthy gunner seat system.

The information herein will be used to design and fabricate a crashworthy, side-facing gunner seat and to evaluate the seat against the requirements of the draft military specification.

Mr. Harold Holland of the Military Operations Technology Division served as project engineer for this effort.

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The poor crash-impact performance of seats designed to current military specifications was revealed by the U.S. Army in the early 1960's. It was discovered that numerous seat occupants were being injured during moderate impacts because of inadequate upper torso restraint, inadequate seat strength, absence of any meaningful vertical crash-force attenuation, and inadequate testing criteria. Following extensive design and testing

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efforts, improved crashworthiness design and testing criteria were developed for Army aircraft seating systems. Due to priorities, however, primary emphasis was placed on developing improved pilot/copilot seats. A program was needed to develop designs, design criteria, and testing criteria for seats occupied by gunners manning window, pintle-mounted weapons in Army helicopters. The purpose of this investigation was to determine the proper mix of all gunner seat design parameters, that is, weight, cost, human factors, operational constraints, ballistic protection, etc. The most effective mix of parametric design criteria was established not only for unarmored seats, but also for integral-armor and modular-armor seats. A number of seat concepts and restraint system designs were developed and evaluated. Selections were made, and seats were designed and built for human factors evaluation using gunners with various clothing and equipment. These evaluations permitted the formulation of a practical military specification for crashworthy gunner's seat systems.

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INTRODUCTION

The poor crash-impact performance of seats designed to current military specifications was revealed by the U.S. Army in the early 1960's. It was discovered that numerous seat occupants were being injured during moderate impacts because of inadequate upper torso restraint, inadequate seat strength, absence of any meaningful vertical crash-force attenuation, and inadequate testing criteria. Following extensive design and testing efforts, improved crashworthiness design and testing criteria were developed for Army aircraft seating systems. Due to priorities, however, primary emphasis was placed on developing improved pilot/copilot seats. A program was needed to develop designs, design criteria, and testing criteria for seats occupied by gunners manning window, pintle-mounted weapons in Army helicopters. In addition to being crashworthy, all designs and criteria must be operationally suitable and economically feasible. The necessity for such criteria and designs is punctuated by the fact that current Army aircraft do not even have seats for gunners operating pintle-mounted machine-guns.

The purpose of this investigation was to determine the proper mix of all gunner seat design parameters, that is, weight, cost, human factors, operational constraints, ballistic protection, etc. The most effective mix of parametric design criteria was established not only for unarmored seats, but also for integral-armor and modular-armor seats. Data attained through literature surveys and visits to Government, technical, and operational agencies led to an understanding of overall requirements so that trade-offs could be made to balance the operational simplicity requirements with the requirements for crashworthiness. A number of seat concepts and restraint system designs were developed and evaluated. Selections were made, and seats were designed and built for human factors evaluation using gunners with various clothing and equipment. These evaluations permitted the formulation of a practical military specification for crashworthy gunner's-seat systems.

The program was divided into three phases. At the completion of each phase a report was prepared and a briefing given on the work accomplished. The tasks performed for each phase were as follows:

- Phase I--Design Criteria Review and Refinement

    1. Survey of literature
    2. Survey of organizations
    3. Recommend revisions to the Crashworthy Gunner Seat draft military specification

- Phase II--Preliminary Design Development

    1. Design development of at least 8 crashworthy gunner's seats including integral-armor, modular armor, and unarmored types

    2. Load, strength, and weight analysis of each concept

    3. Occupant crash hazards analysis to predict statistical probability of spinal injury

    4. Human engineering analysis (including gunner motions and troop accommodations)

    5. Operational suitability analysis (including reliability and maintainability)

    6. Comparative analysis and concept selection

    7. Recommend revisions to the Crashworthy Gunner Seat draft military specification

- Phase III--Design Development of CH-47 Helicopter Gunner Seat System

    1. Design of crashworthy gunner's seat for the U.S. Army CH-47 helicopter

    2. Load, stress, and weight analysis

    3. Occupant crash hazards analysis

    4. Human factors evaluation

    5. Operational suitability analysis (including weight, cost, removal time, environmental analysis, maintenance, and reliability)

    6. Identification of CH-47 modifications necessary for installation of crashworthy gunner's seat

The report is arranged in this general order.

LITERATURE SURVEY

The literature surveyed is listed in the Selected Bibliography. Data obtained can be classified into three categories:

- Side-facing energy-attenuating seat design and test
- Lateral restraint systems design and test
- Current helicopter gunner's seat provisions

SIDE-FACING ENERGY-ATTENUATING SEAT TEST PROGRAMS

Results of all the seat test programs reviewed, including the following, revealed that none of the side-facing seats withstood pure longitudinal crash-impact loads (in accordance with TR 71-22) without failure.

BUNAVWEPS[1] and USATRECOM[2] Test Programs

One of the side-facing seats tested consisted of a tubular-frame seat pan supported at the front by a single energy attenuating strut, and the back was attached to the aircraft side frames by a hinge. Straps from energy attenuators at the ceiling were attached to the seat pan. The attenuator consisted of wire threaded back and forth through holes in a plate.

The seat was tested on a horizontal accelerator sled with the seat oriented in a side-facing position. The acceleration was applied in a longitudinal direction. A pulse of 24.5g with a time base of 0.06 second was applied. The crash load applied to the seat pan through the lap belt caused the fiberglass seat pan to fracture, splitting in half approximately through the front-to-back centerline. The seat pan hinge attachment to the side wall of the aircraft was torn off. No longitudinal attenuation was provided.

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1. DEVELOPMENT OF VERTOL MARK I CRASH-SAFETY TROOP SEAT, Boeing Vertol Company, Report 397, Department of the Navy, Bureau of Naval Weapons, Washington, D.C., May 1965.

2. L. W. T. Weinberg, CRASHWORTHINESS EVALUATION OF AN ENERGY-ABSORPTION EXPERIMENTAL TROOP SEAT CONCEPT, Aviation Safety Engineering and Research, Phoenix, Arizona, USATRECOM Technical Report 65-6, U.S. Army Transportation Research Command, Fort Eustis, Virginia, February 1965.

NADC Test Programs[3,4]

A hammock-type side-facing energy-attenuating seat was developed consisting of a fabric and webbing bucket supported by straps attached to the ceiling with wire-bending attenuators. A spreader tube supported the front of the seat, and diagonal legs attached to the floor stabilize the seat pan. Ball joints allow the seat pan to move in three axes. Diagonal straps attached to the sides of the seat take lateral seat loads. In vertical drop tests, acceleration on the dummy was reduced to 17g with a 42-fps impact velocity. The seat failed sled tests for 95th percentile longitudinal impacts (lateral seat loading) due to lateral tiedown strap or attachment fitting failures. Failed parts were reinforced and tests repeated, but loads on the dummy were far in excess of human tolerance in the lateral direction. These tests showed the necessity of providing lateral attenuation on side-facing seats.

Lateral Restraint Systems and Tests

Significant excerpts from literature surveyed are included in the following paragraphs.

> The diagonal shoulder strap, which is placed on the forward side of the neck, offers much more restraint (in side-facing seats) to expected impact loads than the standard, two-strap harness used by forward-facing personnel. It also requires only one point of release with the lap belt.
>
> Experimental tests conducted by the Navy indicated that a single diagonal shoulder strap with a shoulder band attached improved lateral restraint during transverse deceleration, but it did not prevent the subsequent rebound out of the harness. Fit of the shoulder band for the 5th through the 95th percentile personnel is also a problem.[5]

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3. M. J. Reilly, ENERGY ATTENUATING TROOP SEAT, Boeing Vertol Company, NADC Report NADC-AC-7105, U.S. Naval Air Development Center, Aerospace Crew Equipment Department, Johnsville, Warminster, Pennsylvania, March 1971.

4. M. J. Reilly, ENERGY ATTENUATING TROOP SEAT DEVELOPMENT, Boeing Vertol Company, NADC Report NADC-73121-40, U.S. Naval Air Development Center, Aerospace Crew Equipment Department, Johnsville, Warminster, Pennsylvania, January 1973.

5. J. L. Haley, Jr. , PERSONNEL RESTRAINT SYSTEMS STUDY BASIC CONCEPTS, Aviation Crash Injury Research, TCREC Technical Report 62-94, U.S. Army Transportation Research Command, Fort Eustis, Virginia, December 1962.

Maximum benefit from shoulder straps, for side-facing personnel, is obtained when they are mounted level with or only slightly above shoulder level. Shoulder harnesses in some aircraft have been mounted above head level which minimizes their effectiveness; the angle of the shoulder strap should not exceed 30 degrees to the horizontal.[5]

Knowledge of human response to lateral deceleration forces is very limited, but tests to date strongly indicate that tolerances are lower for this position than for either forward- or rearward-facing body orientations. Human subjects have found the subjective pain threshold to be 9g (average) for a duration of approximately 0.1 second. Even when body restraint consisting of both lap belt and upper torso harness is worn, Sonntag found the maximum voluntary subjective tolerance to be 14.1 peak sled g at 600g/second rate of onset for 0.122 second duration.[6]

More recent tests with the F-111 restraint system (General Dynamics' version) resulted in subjective tolerance levels of 12 to 14g measured on the chest.[6]

CURRENT HELICOPTER GUNNER'S-SEAT PROVISIONS

Two of the principal Army helicopters employing side-mounted, manually operated gun stations are the UH-1 and the CH-47. No seat provisions are made for the CH-47; however, seats are improvised in the field (Figures 1 and 2).

Seats are provided in the UH-1 for side gunners, but the seats have become limited in value. In the UH-1A models, a forward-facing gunner seat was used which was close to the side of the aircraft (Figures 3 and 4). As shown in these figures, the gun was suspended by a bungee or a double link arm. The gunner could lean his upper torso out of the aircraft and fire forward or sideways while strapped to the seat. Depressed-angle and aft firing was difficult from the forward-facing seat. To achieve these gun attitudes, the gunner stood, using a safety belt with monkey harness anchored to the floor (Figure 5).

The need for greater forward firing coverage led to the development of the gun mount shown in Figure 6. With this configuration the pintle was so far out from the side of the aircraft that the gunner was forced to stand on the skid to operate the gun.

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6. G. Kourouklis , et al, THE DESIGN, DEVELOPMENT, AND TESTING OF AN AIRCREW RESTRAINT SYSTEM FOR ARMY AIRCRAFT, Dynamic Science, USAAMRDL Technical Report 72-26 , Eustis Directorate, U.S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, June 1972, AD 746631.

Figure 1. CH-47 Improvised Gunner's Seat.

Figure 2. CH-47 Improvised Gunner's Seat.

Figure 3. UH-1A Forward-Facing Gunner With Swing Arm Pintle Mount.

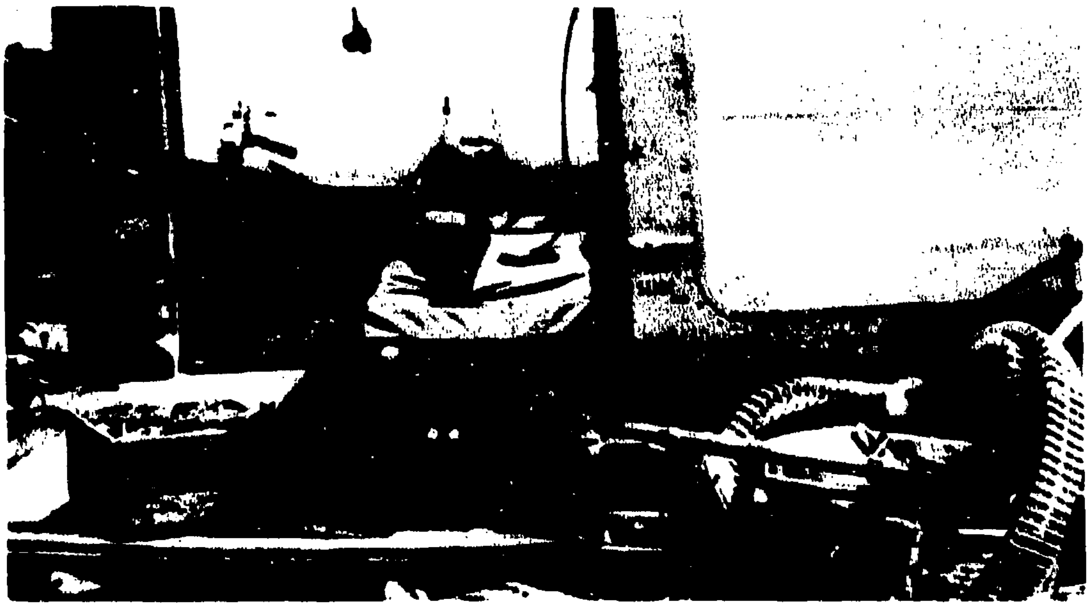


Figure 4. UH-1A Forward-Facing Gunner's Seat - Elastic Cord Mounted Gun.

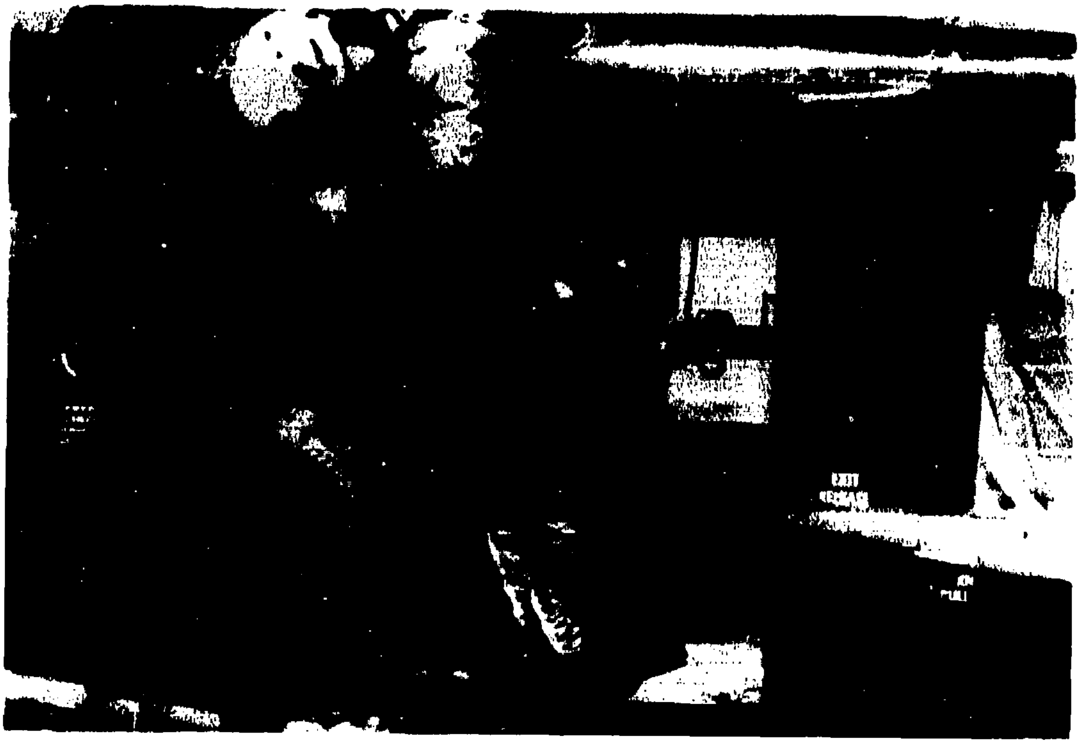


Figure 5. UH-1A Gunner Standing With Monkey Harness Restraint.

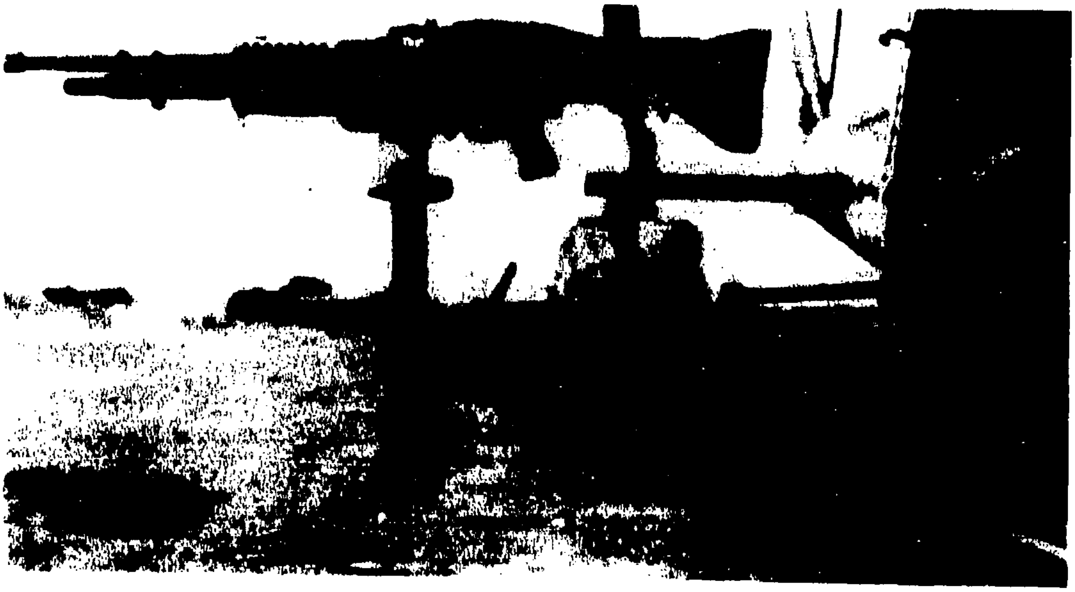


Figure 6. UH-1A Swing Arm Pintle-Mounted Gun.

With the advent of the D model UH-1, the gunner was placed on a longitudinal seat facing the side and the gun was supported from a pintle tube mounted outside the aircraft (Figure 7). The pintle was located close to the outside surface of the aircraft, and the gunner could achieve nearly the entire gun motion envelope while strapped to the seat.

The necessity for greater depressed-angle and forward firing led to the development of a pintle mount which was 18 inches outside of the aircraft (Figure 8). With the pintle moved out, gunner motion was considerably reduced while he was strapped to the seat. The gunner was required to sit on the edge of the seat or stand to maneuver the gun through the required motion envelope. A safety belt with monkey strap tied to the floor was also used, to a limited degree, with this gun mount (Figure 8).

GUNNER RESTRAINT SYSTEM DEVELOPMENT

In the UH-1D the crew chief/gunner had to move back and forth between the gunner's seat and the crew chief station behind the pilot. Existing monkey strap restraint was too restricting so a longer cable system was developed which permitted him to move between the two stations but prevented him from falling out of the aircraft (Figure 9). The system was evaluated by units of the 1st Aviation Brigade and found to be unsuitable for service use for the following reasons:

- The system lock failed to work properly 43 percent of the time. In all tests, the inertia-reel lock malfunctioned (it frequently locked with normal movement and required feeding the cable back into the reel to release the lock; at other times the reel did not lock upon application of shock loads).
- The 8-foot cable allowed sufficient room for crew movements within the aircraft but required removal for normal crew duties outside the aircraft.
- The harness required too much time to put on and remove; there were no provisions for a quick release, for exiting the aircraft in an emergency.
- During a crash or other violent maneuver, the system would not restrain the crew member enough to avoid injury; the system cannot replace the seat belt because it does not hold the man firmly in the seat.
- No positive manual lock is provided for use during an impending emergency.

- The payout cable frequently snags or binds on the gunner/crew chief seat.
- For overall effectiveness, the system provided no greater protection than the old safety harness.

Figure 7. UH-1D Side-Facing Gunner With Lap Belt Restraint.

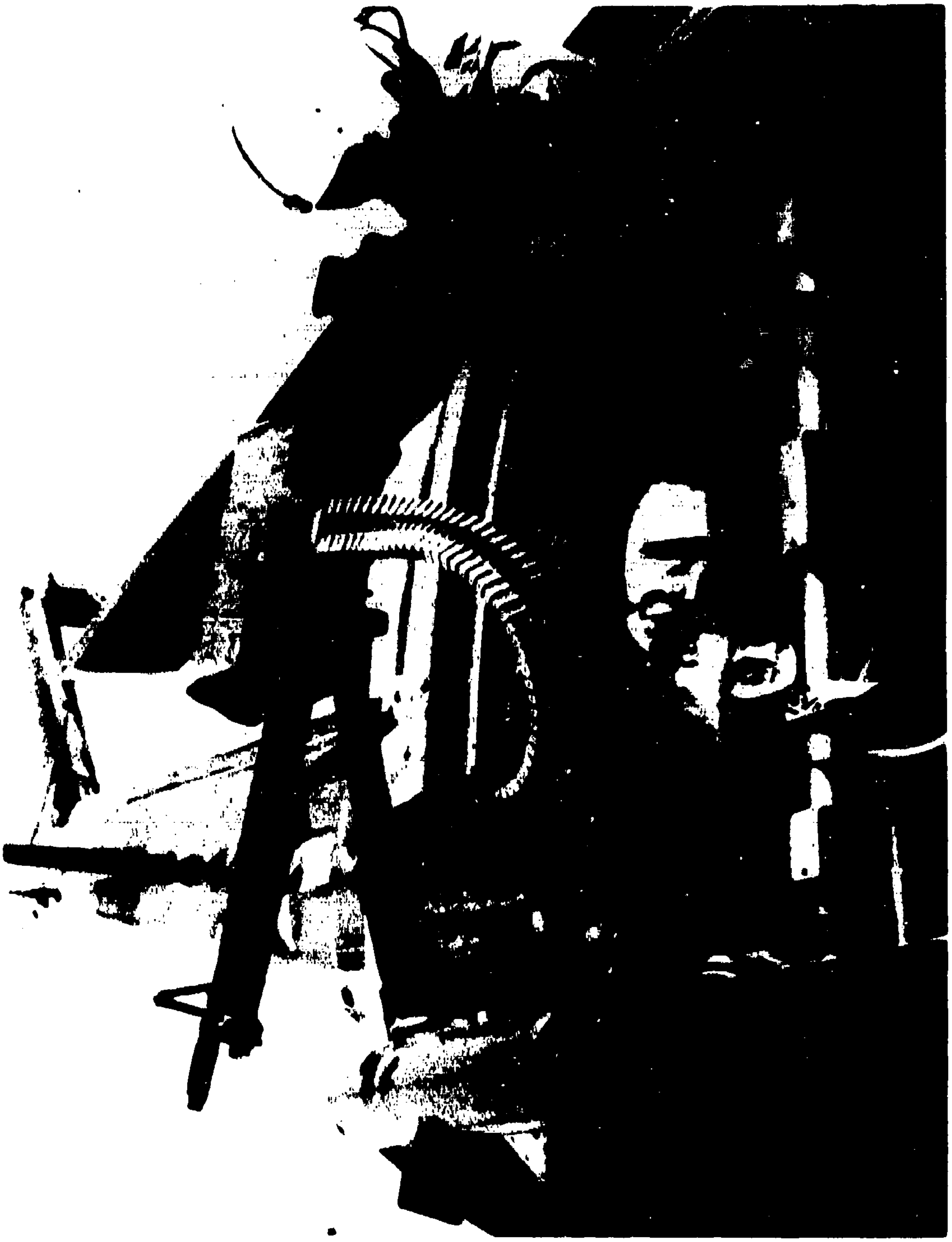


Figure 8. UH-1D Side-Facing Gunner With Monkey Harness.

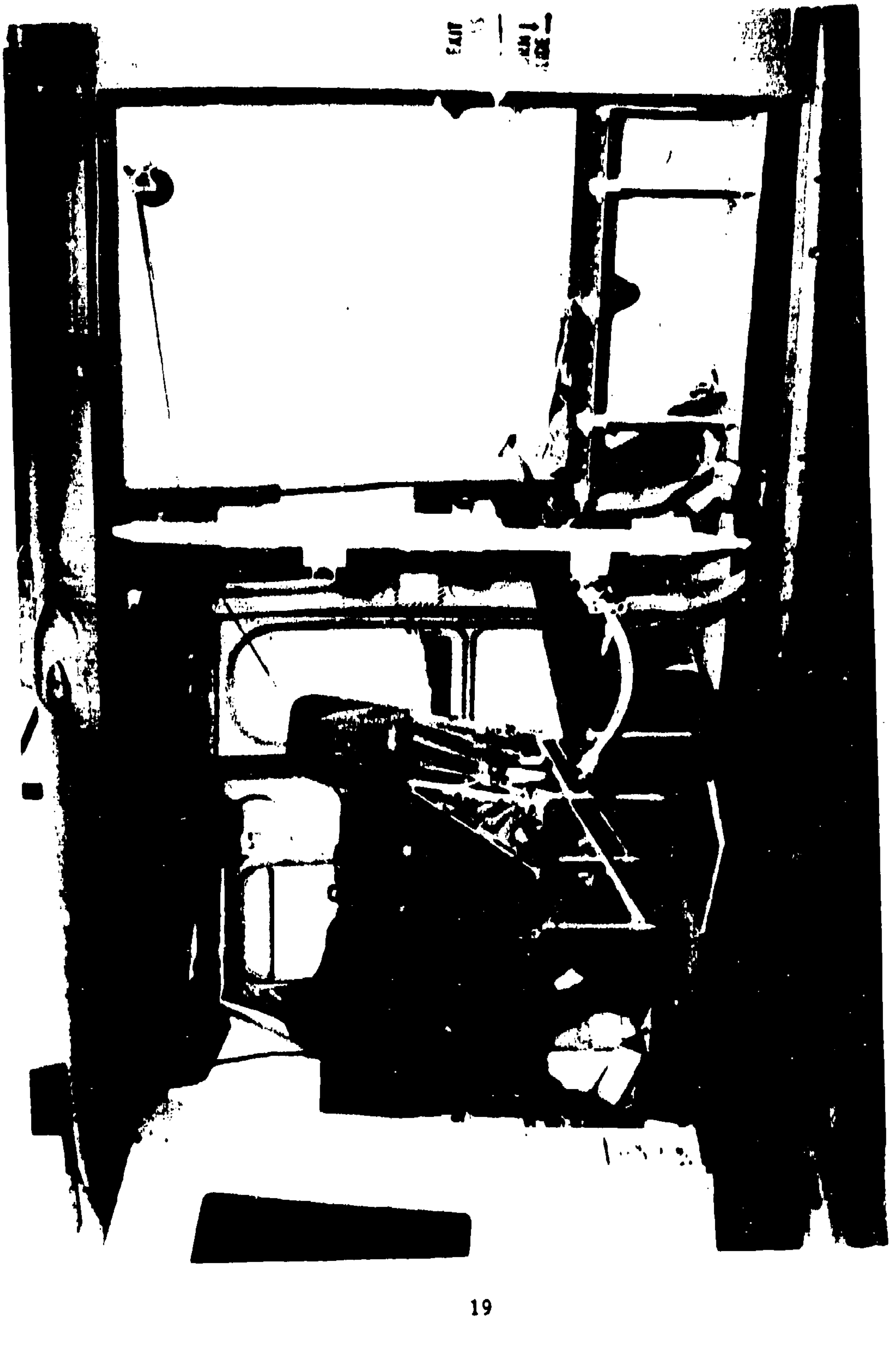


Figure 9. Developmental Retractable Monkey Harness Restraint for UH-1.

SURVEY OF ORGANIZATIONS

DATA FROM ARMY AGENCIES AND COMMERCIAL FIRMS

Visits were made to various military agencies and commercial firms to obtain data useful to the design of crashworthy gunner seats. The data reported in this chapter was obtained as shown in Table 1.

Clothing and Equipment (a.)

The crew chief/gunner's clothing and equipment are essentially the same as the pilot's and copilot's. The gunner wears either the SRU-21/p survival vest or the newly developed combination survival vest and armor plate carrier, the ISVESTA (individual survival vest for aircrew members). The ISVESTA (Figures 10 and 11) can be used without armor plates, with either front or back plate, or with both plates. A weight breakdown of the equipment follows:

Item	Weight (lb)
Clothing	3.2
Boots	4.0
Helmet	3.0
Carrier, Nomex	1.1
Front Armor Plate with Spall Shield (Large)	16.0
Rear Armor Plate with Spall Shield (Large)	19.0
Survival Components	8.0
Personal Weapon (Holster, Pistol, Belt)	4.0
Life Preserver LPU-10/P	3.0
Total	61.3

Gunner Seat Dimensions (b.)

According to the U.S. Army Human Engineering Laboratory (HEL), seat width is dependent upon whether sides are provided or not. An open-sided seat can be as narrow as 18 inches, with 20 inches more desirable, but 22 inches would be required if the seat has sides. The 22-inch width allows for gunner survival gear, body armor, and troop equipment on the lower torso. It also allows for the bideltoid width (elbow to elbow) with life preservers stowed under the armpits in the survival vest. This width, however, does not allow for arm or elbow motion in maneuvering the gun.

Seat depth should be 14 to 15 inches, which allows 1 inch for back armor plate and standoff padding. Additional depth of up to 8 inches is desirable for a combat pack if the seat is to be used by combat troops.

TABLE 1. ORGANIZATIONS SURVEYED

Agency or Firm	Boeing Contact Visit	Boeing Contact Phone	Data Supplied
U.S. Army Combat Training and Development Infantry Agency (CTD)	X	X	d, e, g, Q
U.S. Army Combat Training and Development Aviation School (CTD)	X	X	c, d, e, f, g, Q
U.S. Army Human Engineering Lab (HEL)	X	X	a, b, g
U.S. Army Aviation Systems Command (AVSCOM)	X	X	b, c, d, f
U.S. Army Air Mobility Research and Development Lab (USAAMRDL)	X	X	
U.S. Army Agency for Aviation Safety (USAAAVS)	X	X	c, d, e, g, h, Q
U.S. Army Ballistic Research Laboratories (BRL)	X	X	f, g
U.S. Army Corps Commands	X		Q
U.S. Marine Corps Commands	X		Q
ORO Manufacturing		X	
Pacific Scientific	X	X	
American Safety	X	X	

a. Clothing and Equipment
b. Gunner Seat Dimensions
c. Gunner Motion Envelope Requirements
d. Seat Design Concepts
e. Restraint Systems
f. Gunner Seat Armor Type and Need
g. Gunner Armor Placement
h. Gunner Crash Injury Statistics
Q. Questionnaire Data (see following section)

Figure 10. Gunner Survival Vest With Body Armor (ISVESTA) - Side View.

Figure 11. Gunner Survival Vest With Body Armor (ISVESTA) - Front View.

U.S. Army Aviation Systems Command (AVSCOM) cited a need for the gunner's seat to serve also as a troop seat and to be configured to accommodate troops with combat packs. Sizing an armored bucket-type gunner's seat to accommodate troops would cause the gunner to "rattle around" in the seat. Therefore, AVSCOM recommended that provisions not be made in the armored gunner's seat to accommodate troops. In addition, armored gunner's seats would probably not be used in a utility helicopter due to weight considerations.

Gunner Motion Envelope Requirements (c.)

Those surveyed at U.S. Army Agency for Aviation Safety (USAAAVS) were of the opinion that aiming the gun is rarely done with a side-facing gun installation for several reasons. If the aircraft or target is in motion the gun is not fired at the target but will lead or lag the target. Tracers in the ratio of one in four are always used to aim the gun. Many of the gun sights were knocked off the guns in Vietnam. Even though the gun is infrequently aimed, the opinion was that the capability to aim the gun throughout the entire gun motion envelope is desirable.

AVSCOM stated that extreme freedom of motion on the part of the gunner and fast response in maneuvering the gun are a necessity. Their opinion was that providing the required degree of maneuverability with the gunner strapped to a seat would require a fully gimballed, powered ball turret; strapping the gunner to a fixed seat would inhibit gunner motion.

Those at USAAAVS voiced a different opinion. They said that 90 percent of the required gun motion in the UH-1 can be covered from a fixed seated position, and sliding sideways on the seat permits coverage of the remaining 10 percent. Seat motion is not necessary for maneuvering the gun, but may be necessary for seeing the target if the gun is mounted in a narrow window. The UH-1 has a wide door opening through which the gun is fired, and the normal gun range of operation can be achieved while seated.

U.S. Army Training and Development Aviation School's (CTD) opinion was that a gun installed for a troop assault operation should have the pintle located 18 inches outside the aircraft and the gunner should be capable of extending his upper torso outside the aircraft. It was also their opinion that two types of side gunner station requirements should be established, one for helicopters that land in hostile areas and another for those that land in relatively secure areas. The hostile area helicopters should provide side gunners at doorways where they can lean out or swing out in a seat and fire directly forward and straight down. The gun pintle should be located at least 14 inches outside the aircraft. For

helicopters landing in relatively secure areas, a window installation would be sufficient. The pintle should be located at least 5 inches outside the aircraft, and the motion envelope requirement would be less than that of the troop assault helicopter.

The need for adequate door or window clearance and restraint system extension so that the crew chief/gunner can lean out to observe the tail rotor for clearance during landings in unprepared areas was also pointed out.

Seat Design Concepts (d.)

Seat design concepts are influenced by two principal factors: gunner operations and crashworthiness. The consensus was that gunner operations take priority over crashworthiness. For the seat to be crashworthy the gunner must be strapped to the seat; and if strapped to the seat, his operations are inhibited. The general opinion was that a seat which moved horizontally or vertically to follow the gun would not be practical.

Several seat concept suggestions were made. It was recognized that a side-facing seat is inherently poor for crashworthiness in forward impacts due to the low human tolerance limits in the lateral direction. With this in mind a seat was suggested by USAAAVS which was supported at the back by a single pole. During forward impact the seat would rotate from a side-facing to a forward-facing position. In vertical impacts the seat would slide down the pole as attenuators, attached between the seat and the ceiling, stroked.

Another suggestion made by CTD (Aviation) was a seat which is capable of manually rotating 90° from a normally forward-facing position to a side-facing position when required for gunnery operation. The seat would remain in a forward-facing position through most of the mission and would only be rotated when approaching a hostile area. In the event of an impending crash while the seat was in the side-facing position, with warning from the pilot the seat would be swung to a forward-facing position and automatically latched. The feeling was that there is sufficient time for warning the gunner of an impending crash. When sufficient time is not available for warning, the crash is usually unsurvivable anyway. The opinion was that the advantage of a swiveling gunner seat, which could be faced forward to provide better crashworthy protection, would outweigh the inconvenience of repositioning and the possibility that impact could occur during readjustment. A variation of this type of seat is one that can be rotated to a position at or through a doorway in the side of the aircraft for improved gunner visibility and full gun motion while the gunner remains strapped in the seat. The gun pintle would require mounting on a swinging arm such as used on the UH-1

(Figure 3). This would permit gun aiming through the full 180° azimuth angle while the gunner remains strapped to the seat.

A third suggestion by CTD (Infantry) was to use a fixed side-facing gunner seat. It was their opinion that little gun maneuvering advantage would be gained by having a movable seat. The principal reason for having a movable seat (always having the gunner strapped to the seat for crashworthiness) was not essential to them. A fixed seat with a retractable restraint system, permitting some freedom for maneuvering the gun, would be more desirable. The gunner can sit down if standing at the seat and the restraint system can be manually tightened or automatically tightened by reels. In potentially survivable crashes, there is usually sufficient time to warn crew members who are in on the communication loop with the pilot. The warning generally given by the pilot prior to impact is, "Going in."

Restraint Systems (e.)

Two types of gunner restraint systems are currently provided in some helicopters: the conventional lap belt and the monkey harness. The lap belt is used with a conventional troop-type seat. The monkey harness is attached to the floor and is intended to prevent the gunner from falling out of the aircraft while permitting him mobility inside. Varied comments were received regarding these restraints. The UH-1 monkey harness restraint is infrequently used because it restricts movement. It was designed primarily to prevent the crew chief/gunner from falling out of the aircraft; but if made longer to permit mobility, its purpose is defeated.

The consensus was that a monkey harness should be avoided in new designs. Gunners that fall out with such restraints are beaten against the side of the aircraft and are thrown into the cockpit. Monkey straps are not standard equipment and are provided in only some UH-1's. Gunners frequently operate the guns without restraint and even stand out on the skid to fire forward without restraint. But the restraint system should be designed to keep the gunner inside the aircraft and confined to his seat area.

The standard restraint for the side gunner in the UH-1D is the lap belt on the longitudinal troop seat. The lap belt provided on the UH-1D gunner seat is not long enough for gun firing while seated because the gun pintle has been moved farther outside the aircraft; the gunner, when operating the gun, must sit on the edge of the seat. If the belt were long enough for the gunner to stand or lean out for forward firing, it would fall down around his legs.

A system other than the conventional lap belt or monkey harness is needed. Restraint system requirements for an aircraft like the UTTAS differ from UH-1 requirements. A UH-1 gunner moves about the aircraft and at times hangs out the side with his feet on the skid. A monkey strap serves a purpose for the UH-1 but would not be necessary for the UTTAS or CH-47 where the gunner is more confined and generally remains in the same position. Restraint system requirements should be established considering crashworthiness and operational suitability.

USAAAVS recommended a double shoulder harness reel with shoulder straps attached to the lap belt buckle. This was the most favored of six systems in a USAAAVS energy attenuating troop seat and restraint system evaluation. This concept was also recommended in the USAAMRDL troop seat investigation program. The evaluation also showed that a stowable lap belt restraint is not necessary to provide a clear seat area, since there was no tendency for the occupant to slide across the seat during ingress or egress. Lap belt reels may be necessary if gunner motion requires them.

<u>Gunner Seat Armor Type and Need (f.)</u>

Some of the considerations for determining the need for gunner seat armor are: the gunner's worth to the mission, encumbrance in the performance of gun operation, added weight and cost, gunner's morale and casualty statistics. It was pointed out that the pilot and copilot have armored seats, yet they are redundant, because if one is hit the other can perform the mission. On this basis, the worth of a gunner in suppressing the enemy fire may be of equal value to a pilot or copilot in accomplishing a mission. No statistics are known to exist which would substantiate this assumption.

Another opinion expressed was that the gunner's mobility, ingress, egress, versatility for troop use, and weight limitations take precedence over armor provisions for the gunner's seat. Weight of an armored gunner seat was considered unacceptable for UTTAS but could be acceptable for larger helicopters. It was one opinion at AVSCOM that the gunner is considered least essential to the mission, the order of importance being pilot, copilot, crew chief, and gunner.

Some points were made in favor of an armored gunner's seat. These were the morale problem of providing armor for pilot and copilot but not for crew chief and gunner and the practice of gunners placing fragmentation vests and armor plates on the seat and on the floor for protection. Gunners showed a desire for having armor protection but were reluctant to wear body armor. They preferred the freedom of moving around. Armor was only worn about 20 percent of the time in Vietnam; on this basis morale was not considered a problem. Discipline plays

an important role in the wearing of body armor. Marine gunners wore armor 80 percent of the time as a result of orders to do so. Data on gunner casualties compared to other crew members was obtained from the U.S. Army Ballistic Research Laboratories (BRL) and is presented in Figure 12. However, no data was available on the percentage of flights made without gunners, whether pilots were in armored or unarmored seats, or whether gunners wore body armor. The effectiveness of body armor or the comparison of armor-protected pilot casualties over unarmored gunner casualties cannot be determined from this data.

BRL stated that ceramic body armor is highly effective in defeating 7.62 rounds. Helicopter hits in Vietnam were this caliber nearly 100 percent of the time. Ceramic body armor vests worn by aircrews provide greater coverage than armor worn by ground troops. Aircrew armor weighs 36 pounds, ground-troop armor, 22 pounds; both use boron carbide.

Gunner Armor Placement (g.)

A fully armored gunner seat was considered impractical by most agencies surveyed. The reasons given were high weight and motion restriction if side armor plates were used. Providing side armor plates would necessitate a seat movable in azimuth, and this would entail a motorized drive system. The consensus was that some armor should be provided for the gunner.

HELs opinion was that priority for the placement of armor should be as follows:

1. The bottom of the seat pan

2. Below the gun from the floor to seat height at the aircraft skin

3. The floor under the gunner's feet

4. The seat back

Armor on the forward and aft sides of the side-facing seat was not considered essential due to the protection afforded by the armored pilot seat in the front and by the troops in the rear. Body armor provides front and back protection only; there is a gap between the plates at the sides. Armor for the gunner's seat should be limited to the seat bottom and a short piece in the back which would overlap the back body armor.

CTD Aviation Agency's opinion was that the bottom of the seat pan is the most important area to armor. Most of the hits, while the aircraft is enroute at higher altitudes, come straight up through the floor. Hits during approach to a hostile

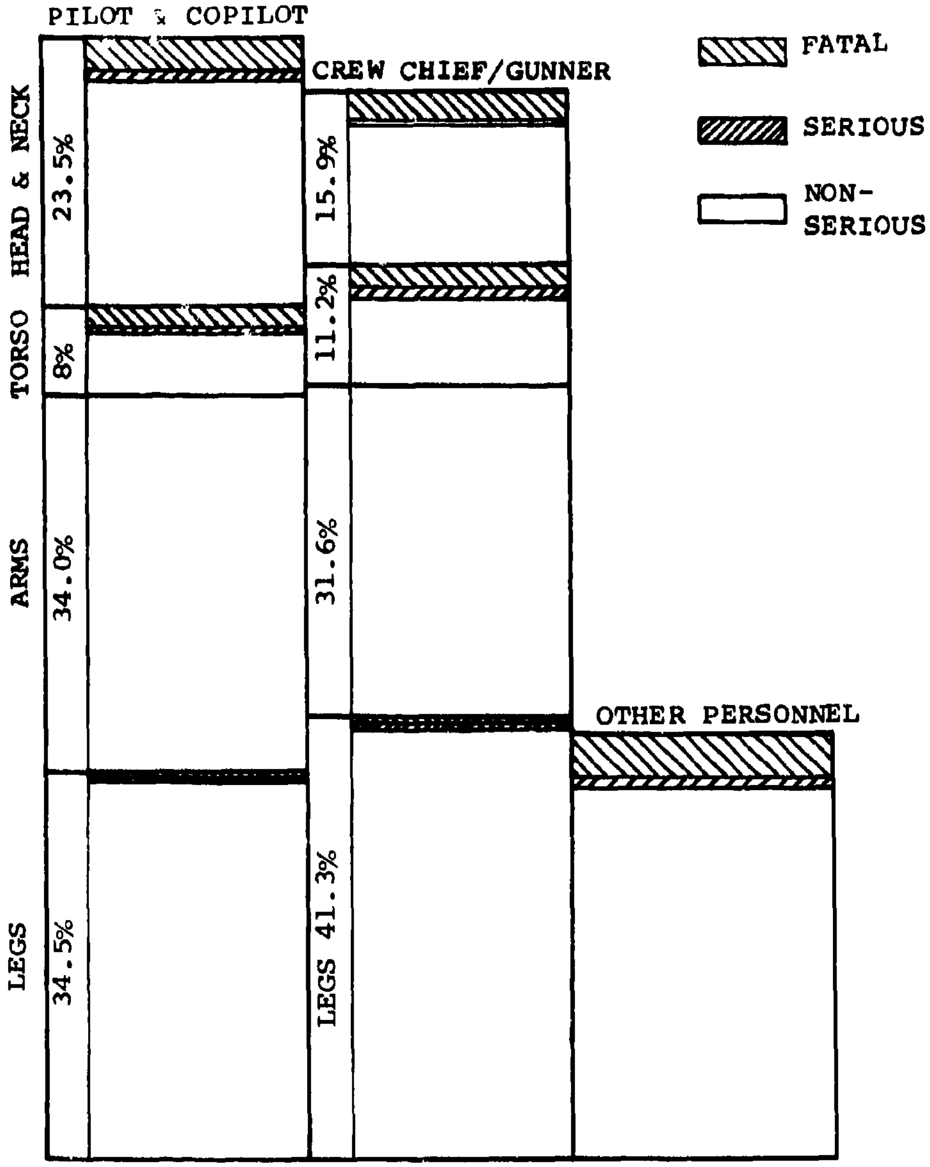


Figure 12. UH-1 Aircraft Wounds and Effect Data.

landing zone usually come through the chin bubble. This is the time side gunner fire is directed forward. The UH-1 pilots usually placed armor vests in the chin bubble. Their recommendations were that crew chief/gunner seat armor should be limited to seat pan only. Pilot seat armor offers some protection for hits coming from the front, and body armor should be used for the random hits coming from other directions.

BRLs data indicates that small-arms fire can be expected to penetrate the aircraft in a uniform random pattern from the lower hemisphere. A high percentage of hits on gunners were in the leg area. Leg armor was developed and 10 kits were sent to the field for evaluation but proved to be too heavy and cumbersome to be adopted. Their recommendation was that, if armor is determined to be necessary for gunners, body armor should be used because of its coverage efficiency and its effectiveness in defeating 7.62 rounds.

At USAAAVS, the need for armor on the gunner's seat bottom was the unanimous opinion. Three incidents of hits through the floor and on the pilot's armored seat bottom were described.

Armor in front of the legs and under the feet was considered second in importance. They recommended a partially armored gunner's seat with armor on the seat pan as a minimum; they also recommended taking advantage of body armor. Use of back body armor may pose a problem; it was rarely worn by gunners in Vietnam. The reason given was discomfort from the heavy weight, which was fully supported by the shoulders, and a feeling of protection by the UH-1 transmission bulkhead.

CTD Infantry Agency's opinion was that a higher percentage of gunners are hit than pilots, and most of the rounds come up through the floor. Scrounged pieces of armor plate were placed on or under the seats. Seat bottom armor is the most important, with armor under and in front of the legs next in importance. Front body armor is worn by gunners, but few wear back armor due to the discomfort. Body armor would be less restricting to gun motion than a fully armored bucket seat. The problem remains in getting the gunners to wear body armor, and this can be resolved by the field command. They recommended that the gunner's seat be provided with armor plate attached to the bottom of the seat pan and that body armor be worn in conjunction with the seat armor.

Gunner Crash Injury Statistics (h.)

The ratio of crew chief/gunner crash injuries compared to pilot and copilot injuries for the CH-47, as obtained from USAAVS, is shown in Table 2. Data shows that for the more severe accidents the chances for the crew chief/gunner being injured are much greater than for the rated crew. For the CH-47

TABLE 2. FLIGHT CREW CRASH INJURIES							
		UH-1			CH-47		
		Rated Crew	Crew Chief	Gunner	Rated Crew	Crew Chief	Gunner
Minor Injuries	S	604	282	267	31	32	17
	PS	43	25	18	10	3	5
	NS	2	2	1	0	0	0
		649	309	286	41	35	22
Major Injuries	S	221	83	72	14	9	5
	PS	65	23	27	6	10	3
	NS	8	5	5	0	0	0
		294	111	104	20	19	8
Fatal Injuries	S	32	22	26	3	5	0
	PS	89	39	32	5	12	6
	NS	265	118	93	38	35	16
		386	179	151	46	52	22

Notes: a. Rated crew includes: Aircraft Commander, Instructor Pilot, Pilot, and Copilot.

b. S: Survivable; PS: Partially Survivable; NS: Nonsurvivable

c. Crew chief injuries were counted separately to compare with gunner injuries; both ride in aircraft under similar circumstances.

d. The reporting period covers Fiscal Year 1968 through Fiscal Year 1972.

aircraft, in partially survivable accidents the ratio of major injuries to the crew chief/gunner was 2 to 1 and fatalities were over 3 to 1 when compared to pilot and copilot. The higher rate is apparently due to the lack of seat and restraint systems. The ratio for crew chief/gunner injuries in the UH-1 as compared to the pilot/copilot is about equal. The data is for noncombat accidents; therefore it can be assumed that the crew chief/gunner was not firing the guns and was restrained in the seat.

QUESTIONNAIRE DATA

A questionnaire was prepared to determine existing helicopter gunner station provisions, gunner operations relative to the seat, restraint system usage, opinions on preference for fixed or movable seat and pintle, types of restraint systems, need for armor, and the priority for its placement. Approximately 400 questionnaires were distributed, but only 143 were answered. Data from the returned questionnaires were classified into the three types of helicopters reported on:

- Utility (Primarily UH-1)
- Medium Cargo (CH-47)
- Troop Assault/Cargo (CH-46)

Those responding for each class of helicopter were separated into two groups. The first group consisted of crew chief/gunners and the second group was others, most of which were pilots.

In general, the questionnaire results showed that most questions were answered for a specific aircraft with the same trends regardless of the classification of the person reporting. Differences in trends resulted for different aircraft reported on because of variance in aircraft configuration and the lack of gunner's seat provisions in some models. Detailed tabulation of the results by type of aircraft and classification of personnel reporting is presented in Appendix A. Total results of the questionnaires are tabulated on the following pages using the questionnaire format. A summary and discussion of these results follows the tabulation.

SUMMARY OF QUESTIONNAIRE RESULTS

The categories into which the questionnaire was divided were provisions, operation, restraint and opinions. General results of the questionnaire in each of these areas are presented.

Questionnaire Total Results Tabulation

THE BOEING VERTOL COMPANY

SIDE-FACING DOOR GUNNER SEAT INVESTIGATION QUESTIONNAIRE

FOR ARMY CONTRACT DAAJ02-73-C-0021

EVALUATORS BACKGROUND DATA

NAME (OPTIONAL) ______________________

UNIT AND LOCATION ______________________

POSITION (CHECK ONE)

(Total of each classification reporting)

76	PILOT	54	CREW CHIEF
11	GUNNER	0	GUNNERY OFFICER
2	OTHER ______________	0	GUNNERY INSTRUCTOR

AVIATION EXPERIENCE

______ YEARS ______ MONTHS

PRIMARY ☐ HELICOPTER ☐ FIXED WING

MODEL AIRCRAFT EXPERIENCE WITH

____

GUNNER SEAT QUESTIONNAIRE

Answer questions for a specific aircraft. Use additional forms for other aircraft. Check NO OPINION column if you have had no experience with question.

1. Aircraft on which answers based ____________________
2. Type of pintle mounted gun used in this aircraft ____________________
3. Experience with this aircraft was in

☐ RVN ☐ CONUS
☐ EUROPE ☐ OTHER ____________

	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION	COMMENTS
PROVISIONS							
1. Are gunner seats provided at the gunner stations	89	1	4	6	39	1	
2. Are seats improvised in the field at gunner stations if no seats are provided	21	34	4	22	43	20	Total All Groups and all Aircraft
3. Is a seat provided for the gunner at other than the gunner station - type	60	17	7	9	29	14	143 Questionaires
4. Are spent cartridge case containers provided	28	25	9	38	38	2	
5. Are stops provided on gun installations to prevent ballistic impacts with the aircraft or rotor	15	5	5	15	83	1	
OPERATION							
1. Does the gunner stand to operate the gun at the gunner station	16	41	19	27	38	0	
2. Does the gunner sight through the gunsights when operating the gun	40	52	23	18	2	5	
3. If a fixed seat is provided does the gunner slide sideways on the seat while operating the gun in azimuth, i.e. swinging from side-to-side	17	20	11	33	17	41	
4. If a seat is provided does the gunner rise up off the seat when operating the gun in elevation	12	19	9	38	25	46	
5. Is depressed angle operation encumbered by ceiling height	76	21	8	15	4	23	
6. Is azimuth traverse firing encumbered by window or door opening width	65	28	8	17	10	8	

	Never or No 0%	Occasionally 25%	Average 50%	Frequently 75%	Always 100%	No Opinion	
7. Does the gunner extend head or shoulders outside the aircraft to aim or fire gun	60	39	14	22	6	2	Total All Groups and All Aircraft
8. Does the gunner spend most of the flight time at the gunner station	2	3	15	56	63	2	
9. Is motion of the gun encumbered by the ammunition chute	40	41	13	20	10	15	
10. Do spent cartridge case containers (if provided) encumber the gunners motions	36	36	12	15	11	28	
11. Are tracers used to assist in aiming gun	3	2	5	44	34	1	
RESTRAINT							
1. Is a safety lanyard and harness provided when operating the gun	35	27	14	22	40	14	
2. Is the gunner strapped to the seat (if seat is provided) while operating the gun	47	22	9	17	14	31	
3. Does the gunner fasten lap belt loosely (if seat is provided) while operating the gun	31	16	10	27	13	42	
4. Is the gunner seat (if provided) equipped with a lap belt	21	10	2	15	38	46	

OPINIONS

1. What is the optimum gunsight height when gun is level: eye level __10__, neck level __15__, chest level __72__, abdomen level __38__, other __2__, where ______.

2. What should be the minimum clearance between the end of the gun and the front of the gunner __12 in

3. Which would you prefer?

47 Horizontally movable seat and fixed pintle mounted gun

44 Fixed seat and gun with horizontally movable pintle mount

43 Fixed seat and pintle mounted gun fixed at one point

4. Which would you prefer?

44 Elevating seat and pintle mounted gun fixed at one point

48 Fixed seat and gun with vertically movable pintle mount

36 Fixed seat and pintle mounted gun fixed at one point

5. Which would you prefer?

77 A fixed seat with a safety ("monkey") harness worn by the gunner which is attached to the seat allowing the gunner to stand and operate the door gun?

55 A moveable seat within which the gunner sits, restrained by a lap belt and shoulder harness while operating the door guns?

7 No seat, but make a safety ("monkey") harness available at the gunner station to prevent the gunner from falling out of the aircraft?

1 No seat and no restraint (safety) harness at all? Why? ______

Do you consider the concept you prefer to be practical?
YES 124 NO 8 If no, why not? ______

6. Do you believe that helicopters with side-facing door gunner stations and armored pilot/co-pilot seats should also provide a seat with armor protection for each door gunner?
YES 115 NO 25 If no, why not? ______

7. Number the following locations for placing armor relative to the gunner in order to priority

Back 3rd Bottom 1st Forward Side 4th Rearward Side 5th

Front 2nd

8. Remarks:

Provisions

Gunner seats are nearly always provided on the UH-1 aircraft, but are never provided on the CH-46 and CH-47 aircraft. Gunner seats are frequently improvised in the field for the CH-47, occasionally improvised for the CH-46 and are frequently improvised for the UH-1 when the standard seats have been removed. CH-46 and CH-47 gunners sit on a troop seat when not at the gunner station. Spent-brass containers are frequently provided for the CH-46 aircraft, but are only occasionally provided for the UH-1 and CH-47 aircraft. Gun motion stops are nearly always provided on all aircraft.

Operation

The UH-1 gunner stands occasionally to operate the gun, but the CH-46 and CH-47 gunners stand most of the time. UH-1 gunners frequently slide sideways and rise up off the seat in operating the gun (CH-46 and CH-47 have no seats). Ceiling height and door or window width occasionally encumber gun operation in all aircraft. Ammunition chute and spent-brass containers occasionally encumber gunner motion. UH-1 gunners extend head or shoulders out of the aircraft an average amount of time to aim or fire the gun, but CH-46 and CH-47 gunners almost never do.

All gunners occasionally sight through the gunsight. Tracers are used to assist in gun aiming nearly all the time. Gunners of all aircraft spend most of the flight at the gunner station.

Restraint

A safety lanyard (monkey harness) is provided about half the time in the UH-1, nearly always in the CH-46, and almost never in the CH-47. UH-1 gunners use a lap belt which is loosely fastened about half the time while operating the gun.

Opinions

Chest level was selected as the optimum gunsight height and 12 inches the minimum clearance between end of gun and gunner.

No trend was established in selecting a combination of vertically or horizontally movable seat and pintle mount or fixed seat and mount. Each of the six combinations received approximately the same number of votes.

The monkey harness restraint system was preferred by most and the remainder (42 percent) preferred a lap belt and shoulder harness in a movable seat.

An armored gunner seat was preferred by 82 percent. Preference for placement of armor was in the following order:

1. Seat Bottom
2. On Floor and Sidewall in Front of Seat
3. Back of Seat
4. Forward Side
5. Rearward Side

CONCLUSIONS FROM ORGANIZATION SURVEY

The principal conclusion reached as a result of the surveys and questionnaire data review was that the different types of helicopters have different requirements for gunner operations, gun motion envelopes, restraint systems, and seat installations. The various requirements are due to the nature of the mission performed by the aircraft and the geometrical arrangement of the seats in the aircraft. In the formulation of a Gunner Seat Military Specification for crashworthy seat design, satisfying the requirements of various types of helicopters such as UH-1, UTTAS, and cargo type helicopters must be considered.

Principal factors considered in determining the approach to designing a crashworthy gunner's seat are gun operation, motion envelope requirements, crashworthiness (including occupant restraint), ballistic protection, weight, and simplicity. Each of these factors was considered during the literature and organization surveys, and conclusions were reached.

Gun Operation and Motion Requirements

Much of the operational data was based on operations in Vietnam. Troop assault operations with UH-1 aircraft were conducted directly into hostile landing zones. Forward fire during the approach was of utmost importance. This necessitated the movement of the gun pintle well outside the aircraft and resulted in the gunner extending his upper torso outside the aircraft and at times even standing on the skid. In the UH-1, a gun-motion envelope of ±90° azimuth and 90° depression was required.

Operations with cargo helicopters were generally into relatively secure areas. The small window openings in which the guns were mounted and narrow angle of fire were adequate for cargo helicopters. The gun-motion envelope required for the CH-47 is only ±45° azimuth and 45° depression.

The UTTAS, which is to replace the UH-1, does not have the gun-motion capability of the UH-1. Gun-motion requirements for the UTTAS are ±70° azimuth and 70° depression. Some concern was voiced over the UTTAS's limited gun motion and the restricted window opening. However, the conclusion reached

is that the UTTAS will not be used in the same manner as the UH-1; the forward suppressive fire will probably be provided by other aircraft.

Crashworthiness

The consensus was that for better crashworthiness, the gunner's seat should face forward rather than sideways. Human tolerance to lateral impact is low. In addition, for a seat to be crashworthy the gunner must be restrained to the seat. A gunner must face sideways and be free to move away from the seat to best perform his gunnery operation. The consensus was that a gunner's seat which moves vertically and horizontally to follow the gun-motion envelope while maintaining the gunner restrained to the seat would be too costly, too complex, and too heavy; a fixed seat with retractable restraint was the better approach.

A rotating seat capable of facing forward or sideward was also recommended to improve the crashworthiness of the side-facing seat. Such a seat would face forward for normal takeoff and landing, through most of the flight, and during impending crash impacts; but it could be swiveled 90° to perform the gunnery operation. The improved crashworthiness of such a seat during a high percentage of its use would outweigh the inconvenience of adjustment and the possibility that impact could occur during readjustment. Such a seat would be optimum for crashworthiness and gunner operations.

The conclusion is that movable seats, to keep the gunner strapped to the seat for crashworthiness while permitting full gun motion, are not necessary. The limited gun-motion envelope of cargo helicopters and the reduced gun-motion requirements of UTTAS over the UH-1 permit gun operation from the relatively close confines of a fixed seat with a retractable restraint system.

Use of monkey harness restraint does not appear to be a satisfactory approach because of the problems encountered with it in the UH-1 and because there is not as great a need to prevent falling out of CH-47 and UTTAS type aircraft.

The more likely approach to a restraint system is a conventional lap belt/shoulder strap configuration attached to the seat, with reels which allow some motion away from the seat. Loose attachment to the seat is maintained during gunnery operation, and immediate restraint to the seat is provided simply by sitting down.

Ballistic Protection

The consensus was that some ballistic protection should be provided in the gunner's seat. The amount to be provided must be determined. The more armor provided, the heavier and more complex the seat will be and the more encumbered the gunner becomes in performing the gunnery operation.

Armor on the seat pan is generally considered the first priority. The second priority for armor placement is not on the seat but on the aircraft in front of the gunner's legs; third is on the seat back. A minimum, satisfactory armored seat would consist of seat pan armor and partial back armor used in conjunction with front and back body armor.

Weight and Simplicity

For a seat to be crashworthy, the gunner must be strapped to it during a crash. However, to have the gunner strapped to the seat at all times and not inhibit gunnery motions would require a heavy complex motor-driven turret-type seat. The gunner seat to be practical must be light weight and simple; therefore a trade off must be made between crashworthiness and gunnery operation.

CRASHWORTHY SEAT SYSTEM DESIGN DEVELOPMENT

DESIGN CONSIDERATIONS

Three basic areas are considered in designing a crashworthy seat: geometry, restraint, and crashworthiness. The basic geometry is determined by what the seat must accommodate and how it is to be used. The capability of the restraint system influences the seat motion requirements. Crashworthiness requirements establish need for controlled deformation and stabilization provisions.

Basic Seat Geometry

In determining the gunner's seat dimensions, consideration must be given to accommodating body armor and survival gear. In addition, a gunner's seat must accommodate a troop with combat assault pack or medium rucksack and associated equipment.

Configuration is a determining factor in establishing seat width. Seats without sides can be as narrow as 18 inches, allowing equipment worn by occupants to hang over. A minimum inside width of 20 inches is needed on seats with sides to accommodate occupants with equipment.

Seat pan depth should be 15 inches for the seating area. An additional extension of up to 8 inches is desirable to accommodate a combat assault pack. A minimum extension of 5 inches for the pack should be provided, making the minimum seat depth 20 inches. Pack extension may taper to 10 inches wide at the back. The extension applied only to unarmored seats, as it is impractical to accommodate a combat pack in an armored seat.

The seat pan should be located 17 to 18 inches above the floor. The 18-inch height is maximum for accommodating the 5th percentile leg length, while 17 inches is the minimum height for adequate seat stroke. A 5° slope is required on the seat pan surface. This can be accomplished by sloping the seat frame or by sloping the seat pan fabric or the cushion within the frame.

Restraint System

A single diagonal shoulder strap provides better restraint for lateral acceleration of an occupant than a double shoulder strap system. The reason is that, for a given lateral crash acceleration on the occupant, the smaller the strap angle with the horizontal the lower the load in the strap. Lower loads reduce strap elongation and minimize occupant motion relative to the seat. However, a single diagonal strap is not suitable

for the side-facing gunner's seat because the strap slips off the gunner's shoulder as he leans aft to maneuver the gun.

Double shoulder straps with independent reels are also not satisfactory. As the gunner moves to one side, the strap on that side tightens around the neck and the opposite strap will slip off the shoulder. The other strap will slip off as the gunner swings the gun to the opposite side. A conventional lap belt shoulder strap system can be expected to have additional problems during gun maneuvering. As the gunner stands up, the shoulder strap load may pull the lap belt buckle up to his chest, and the buckle may move to the side as he swings the gun to the side.

The recommended restraint system resolves many of these problems and permits the gunner to move away from the seat for gunnery, yet restrains him as soon as he sits down. The recommended system is the result of mockup development and will be discussed later in detail.

Crashworthiness

In a crash impact, the gunner's seat must deform or stroke in a controlled manner and in the direction of the impact load. Vertical impacts are given more consideratior because of the high frequency of occurrence in this direction and because of the low human tolerance to vertical impact. During vertical impact the seat must move downward at a specific resistive force. Guidance and support of the seat during vertical motion or stroke are necessary. Guides and support on the floor can be considered; they tend to be too heavy for unarmored seats, but are appropriate for floor mounting of heavy armored seats. A seat slung from the ceiling with tension straps and energy attenuators will provide the necessary guidance and support for the least weight and should be the principal method employed for unarmored gunner's seat concepts.

Supporting the seat for normal use yet allowing it to stroke freely during impact while maintaining guidance and stability is a problem. In a ceiling-suspended seat, the energy attenuating device must be located above the seat, and the seat should be fully suspended from it. Supports below the seat pan (such as diagonal braces or cables) should only stabilize the seat and should freely collapse as the seat moves down. Rigid legs, even with deforming or stroking features, should not be used because attenuating devices above and below the seat do not tend to act together. Center-of-gravity shifts due to variations in occupant weight or equipment carried will cause the load distribution to the attenuators to vary. As the load is shifted toward one or the other attenuator, that attenuator will stroke first, and the threshold stroking load for the second attenuator may not be reached (Figure 13).

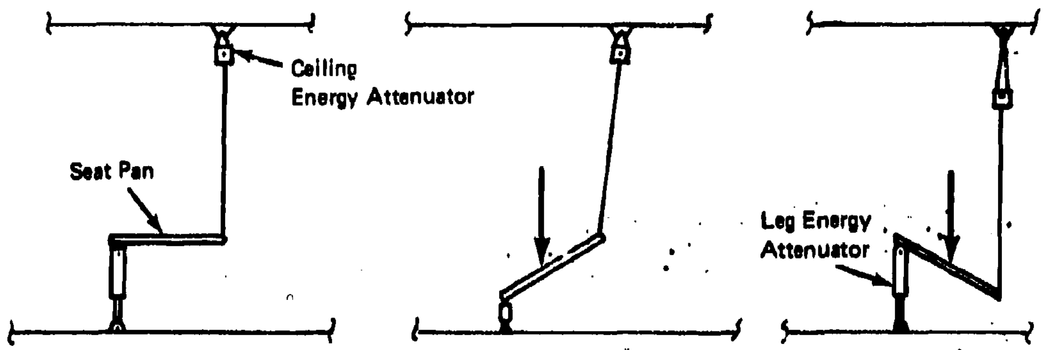


Figure 13. Effects of Attenuators in Series.

Supporting the seat fully from above and minimizing the encumbrances to gunners is the desired goal. A seat pan fully supported from above (Figure 14a) is ideal structurally but unacceptable operationally due to the lack of elbow clearance. This arrangement can be modified to permit more elbow clearance by curving the strap supporting the front of the seat by using a catenary side panel (Figure 14b).

An unobstructed seated area can be achieved by a cantilevered arrangement (Figure 14c). In this arrangement, the seat pan is supported by a tension and compression member at the back of the seat. A back rest is provided along the face of the inclined tension members. A well can be added behind the back rest surface to accommodate a troop combat assault pack.

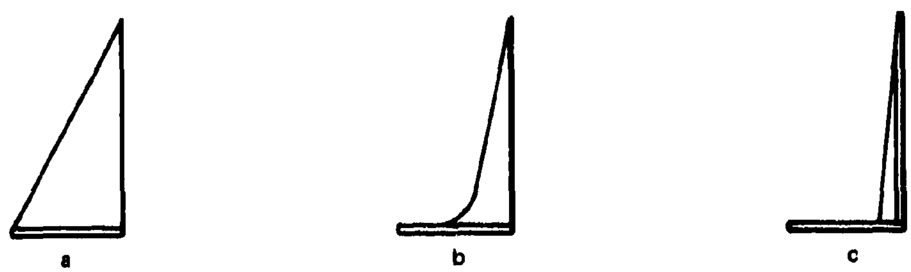


Figure 14. Typical Seat Pan Ceiling Suspension Methods.

SEAT DESIGN COMMON FEATURES

The following systems are common for all or most of the seat concepts. Exceptions will be discussed with the individual descriptions of the different concepts.

Restraint System

The restraint system for all gunner seat concepts is shown in Figure 15. The only exception is the lap belt anchor attachment. Fixed seat concepts use inertia reels at the lap belt anchorage as in the basic concepts. Seats which move sideways during gunnery operations have fixed lap belt anchors; reels are not considered necessary. Methods of installing the shoulder harness reel vary with some concepts, but the same configuration is used.

Features of the restraint system are lift-lever lap belt buckle, two inertia reels at the attachment of the lap belt to the seat pan, and an inverted-Y shoulder harness with a single inertia reel. Full retraction of the shoulder straps is not provided. However, this should not present a problem because the seat will be used mostly by crew chiefs and gunners, who will become more familiar with the system and who do not require rapid ingress and hookup as troops do. Shoulder straps can be connected to the buckle after the lap belt is fastened. Lap belt and shoulder straps are released simultaneously by lifting the buckle latch. Further refinements to this system were made during the gunner's seat mockup evaluation. They are discussed later.

Energy Attenuation System

Vertical energy attenuation is accomplished in all ceiling-mounted seat concepts by using a wire-bending attenuator (Figure 16). Controlled force deflection is produced by bending and unbending wire as it passes over rollers during seat stroking. The force-deflection curve is designed to be compatible with the dynamic response to a 50th-percentile occupant, thereby minimizing the probability of spinal injury for the full range of 5th- through 95th-percentile gunners. Energy attenuation in forward and lateral directions is provided by various devices for the different seat concepts and will be described with each concept.

Seat Pan

For all unarmored seat concepts the seat pan is constructed of a tubular frame and covered with a polyester fabric. The frame is positioned parallel to the floor to permit the maximum seat stroke. Fabric covering the tubular frame is tailored

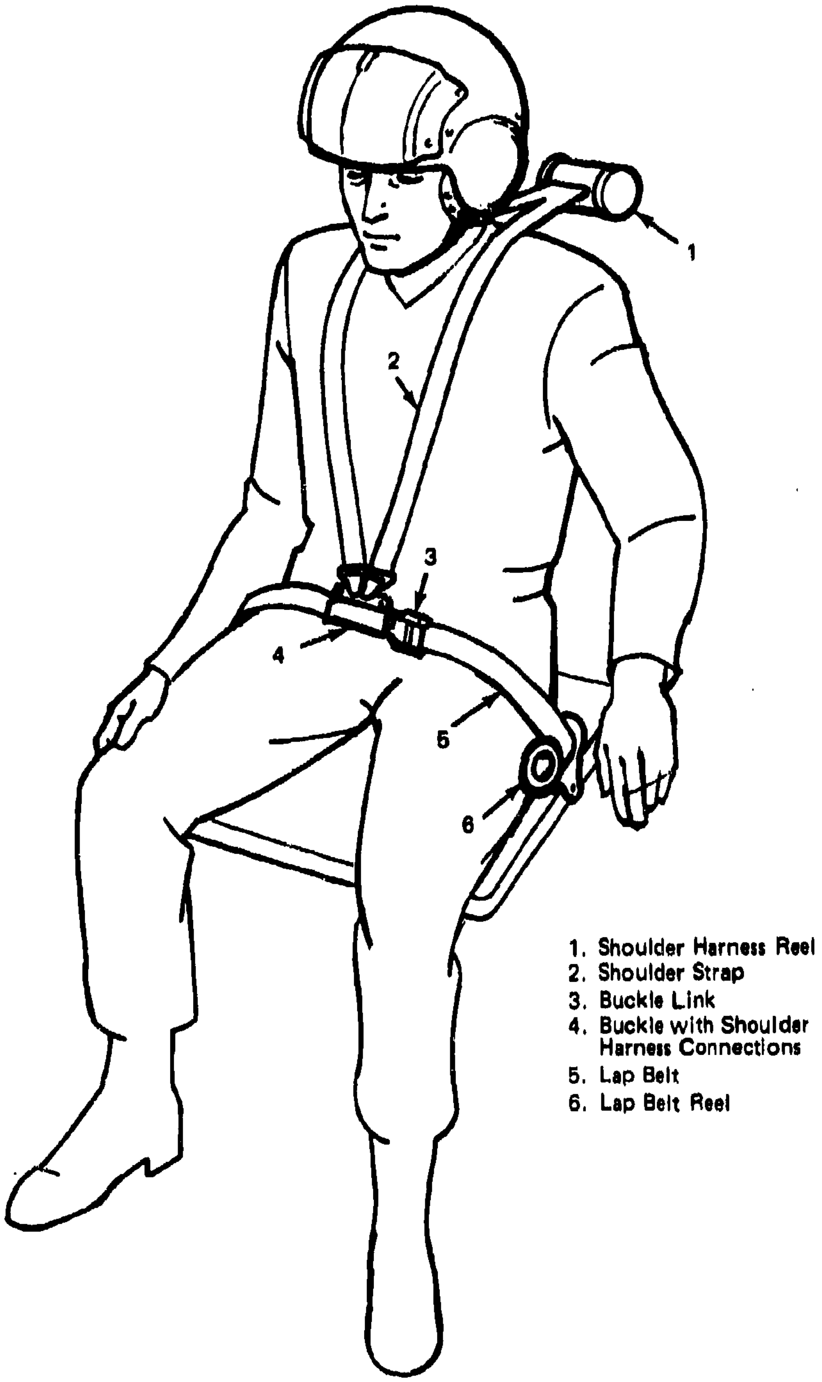


Figure 15. Side-Facing Gunner Restraint System.

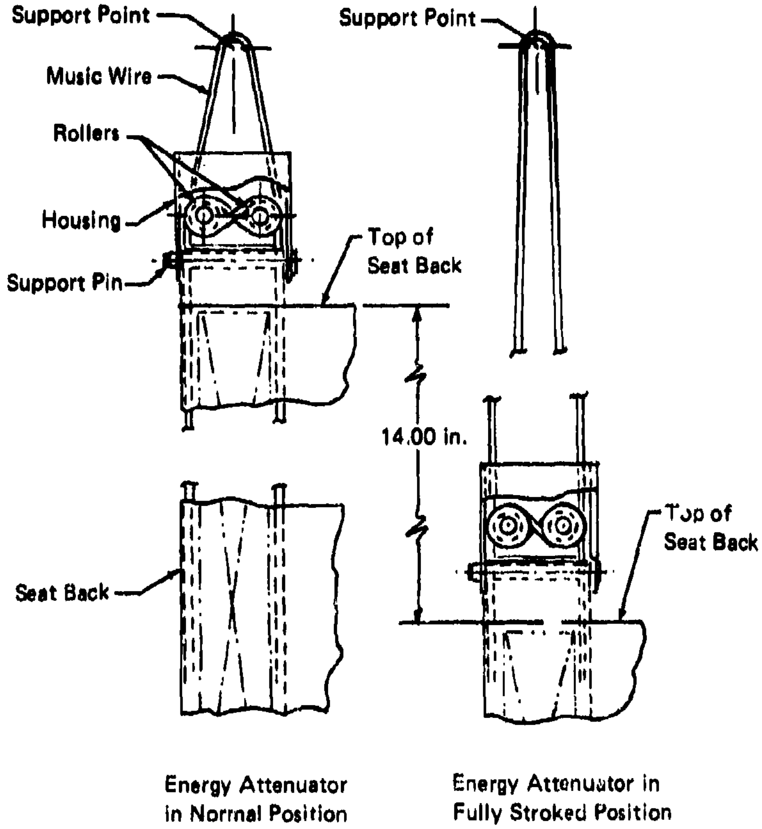


Figure 16. Compact Wire-Bending Energy Attenuator.

to conform to the occupant's buttocks and to allow approximately a 6° slope back from the front of the seat for occupant comfort.

Design Loads

The seats are designed for loads induced by a 95th-percentile fully equipped gunner for all directions except vertical. In the vertical direction, weight of a 50th-percentile gunner with full equipment is used.

A preliminary load and stress analysis was performed for each concept to determine feasibility of design and to size members to obtain weight estimates. The acceleration in various directions and effective design loads were also determined.

DESIGN CONCEPTS

Design concepts are divided into three categories: unarmored, integral armor, and modular armor.

Unarmored

The unarmored seats are generally lightweight construction consisting principally of tubing and fabric.

Concept A--Concept A, shown in Figure 17, is a ceiling-mounted, side-facing seat stabilized at the floor and suspended by wire-bending energy attenuators. The seat pan is of tubular construction and is hinged to a tubular back frame assembly to permit seat folding. The seat pan is cantilevered from the back frame and suspension straps. This arrangement provides an unobstructed seating area and eliminates legs under the seat, which would affect vertical stroking. Fabric covers the seat pan and back. A pocket is built into the seat back to accommodate a combat assault pack, and a fabric flap covers the pocket for normal gunner use. Quick disconnect fittings attach the seat to the ceiling and floor. Adjusters at the ceiling permit seat tensioning.

Energy attenuation is provided in the vertical, forward, and lateral directions. During vertical impacts, the wire-bending attenuators at the ceiling stroke, and the seat moves freely downward stabilized by the longitudinal diagonal struts. The seat pan height is 17 inches, and the seat strokes vertically 15 inches. Forward impacts will cause the diagonal struts, which are telescoping-tube torsion-wire energy attenuators, to stroke. During lateral impacts, the seat will move frontward or backward as the annealed stainless-steel diagonal cables yield at a predetermined load. Stroking of the

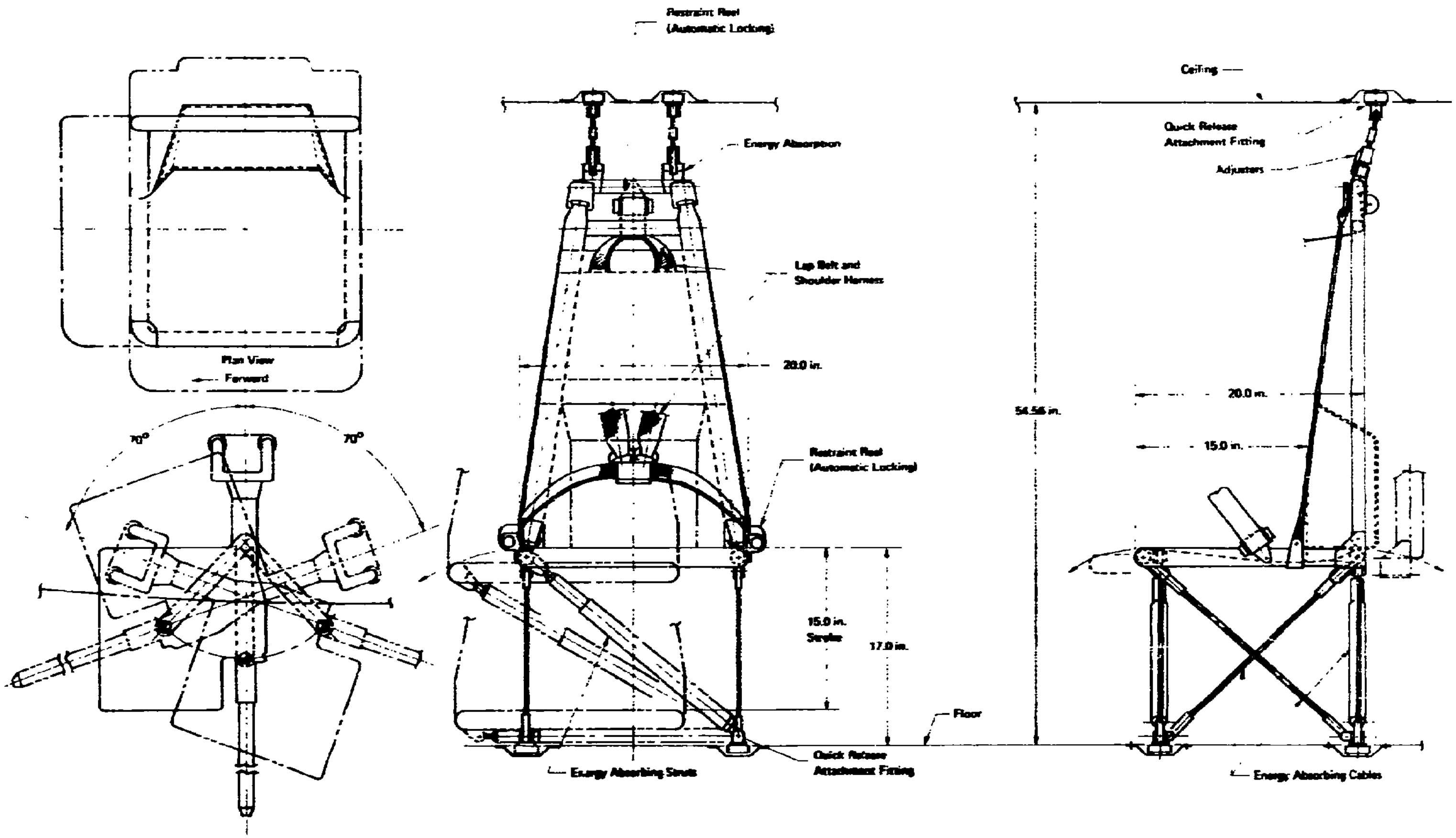


Figure 17. Concept A - Ceiling-Mounted Fixed Unarmored Gunner's Seat.

wire-bending attenuators at the ceiling will also occur during longitudinal and lateral impacts.

A fixed seat is used in this concept; therefore, to minimize gun butt travel in azimuth, an extension arm is attached between the gun and the pintle. Overall travel of the gun butt is reduced from 36 to 22 inches in an arc of 140° (Figure 17).

The restraint system shown in Figure 15 is used. The shoulder harness reel is attached to the seat back top tube. The reel strap passes under a second tube at shoulder height and through a guide where it is connected to the inverted-Y double shoulder strap. Lap belt reels are mounted on both sides of the seat to permit gunner motion away from the seat.

Weight of the seat without the restraint system is 10.4 pounds. The restraint system weight, which includes three inertia reels, is 3.0 pounds.

Concept B--Concept B, shown in Figure 18, is similar to Concept A with exception of the mounting provisions. Rather than using quick disconnect fittings at the floor, the seat is attached to a carriage which rolls on curved rails. Attachment at the ceiling is to rollers in a curved track. Lap belt attachment to the seat pan is fixed, because reels do not appear to be necessary for a movable seat.

Seat operation consists of rolling the seat on the tracks by moving the feet. The seat track is curved in an arc described about the center of the gun pintle. As the gun is swung in azimuth through its horizontal motion envelope, the gunner and seat can maintain alignment with the gun. The seat remains unlocked during gunnery operations. Inertia locks are provided in the floor track and ceiling track which will automatically lock the seat to the track when accelerations exceed a given level, and a manual lock can also be provided.

Weight of the seat without the restraint system is 28.4 pounds. Restraint system weight, which includes one inertia reel, is 2.0 pounds.

Concept C--Concept C, shown in Figure 19, is similar to Concept A with exception of the mounting provisions. The seat is mounted on a turntable in place of the quick disconnect attachments to the floor. Ceiling attachment is to rollers in a curved track.

The turntable feature of the seat is primarily for crashworthiness, rather than gun operation. Side-facing seats provide the least crashworthy protection because of the low human tolerance to lateral acceleration. For this reason, it is desirable that all seats face forward or aft. A gunner's seat

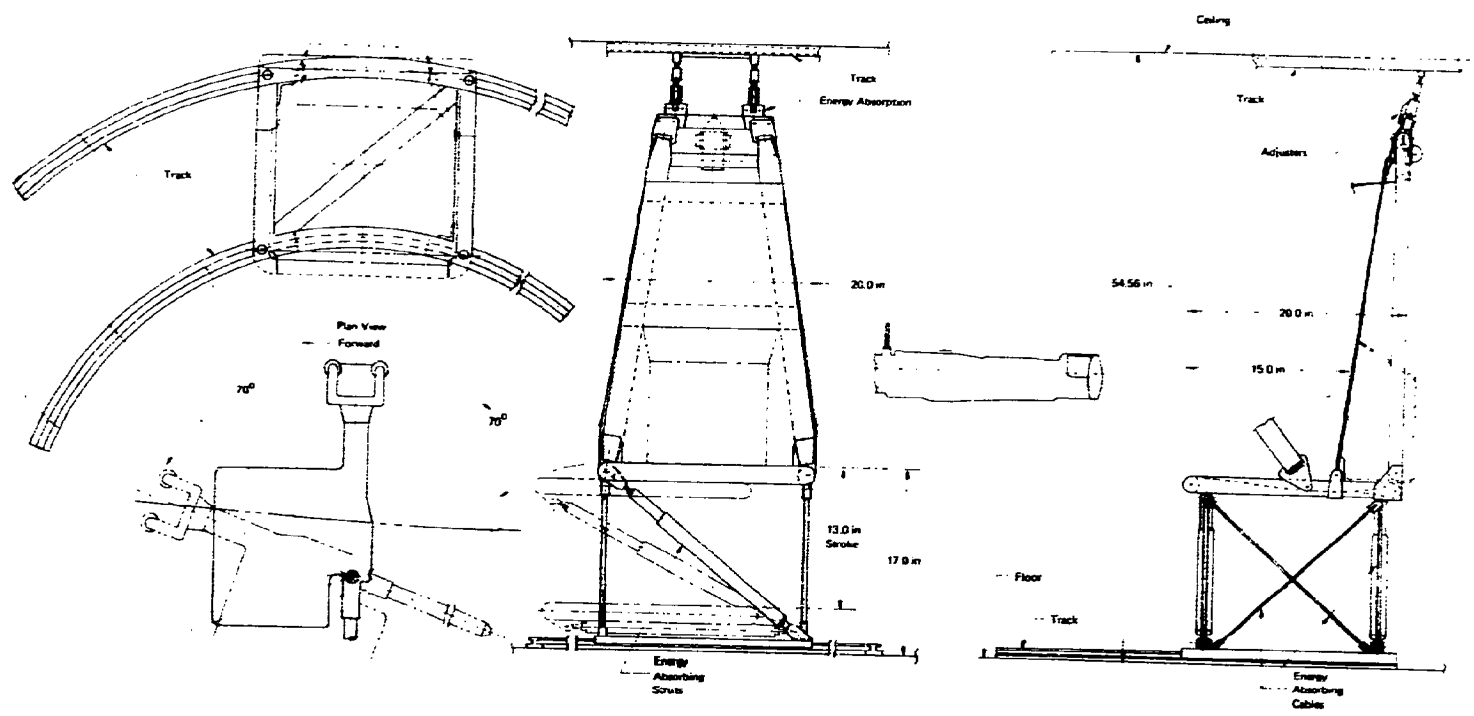


Figure 18. Concept B - Ceiling-Mounted Movable Unarmored Gunner's Seat.

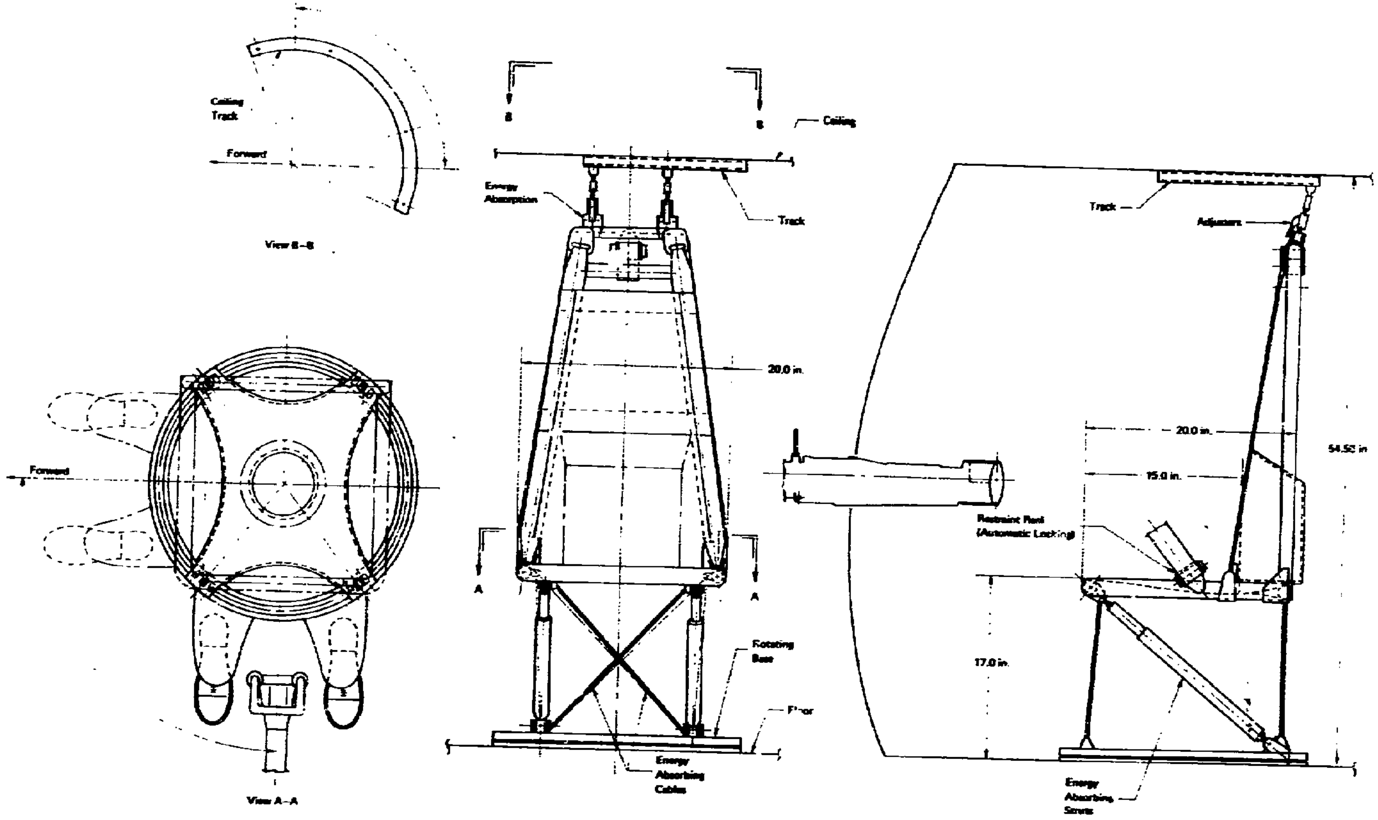


Figure 19. Concept C - Ceiling-Mounted Swiveling Unarmored Gunner's Seat.

with a turntable can be placed in a forward- or aft-facing position for takeoff and landing and when the gunner is alerted to an impending crash. Gunnery operation can be performed by rotating the seat 90°. Locks are not essential on the turntable because the center of gravity of the gunner is approximately on the center of rotation and impact loads would not tend to rotate the seat.

The restraint system is the same as used in Concept A (Figure 15). Lap belt reels are needed because of the limited seat motion. A pintle-arm extension, as shown in Concept A, is desirable to minimize gun butt travel.

Weight of the seat without the restraint system is 16.8 pounds. Restraint system weight, which includes three inertia reels, is 3.0 pounds.

Concept D--Concept D, shown in Figure 20, is configured for CH-47 geometry. It is a ceiling-mounted, side-facing seat stabilized at the sidewall and suspended by wire-bending energy attenuators. The seat pan is constructed of tubing and is hinged to a tubular back frame assembly permitting seat folding. A pantograph attached to the side frames supports the front of the seat and stabilizes the seat during vertical stroking. Longitudinal stability is maintained by diagonal straps attached to the sides of the seat and anchored to the floor. An energy attenuator is incorporated in the aft strap floor attachment. Fabric covers the seat pan and backframe. Quick disconnect fittings are used for ceiling and floor attachments.

Energy attenuation is provided in the vertical, forward, and lateral directions. During vertical impacts, wire-bending attenuators at the ceiling stroke, and the seat is free to move downward stabilized by the pantograph which maintains the seat pan in a level attitude. The seat pan height is 30 inches and the seat is capable of 20-inch vertical stroking. Under forward crash accelerations, the seat moves forward, rotating about the pantograph pivot point as the wire-bending attenuator in the aft diagonal tiedown strap strokes. The wire-bending attenuators at the ceiling will also stroke. Minimal lateral attenuation is provided. The seat pan will not stroke laterally, but some lateral attenuation is provided by the ceiling attenuators and deformation of the seat back tubular frame.

A fixed seat is shown in this concept because of the limited range of gun motion required for the CH-47. However, the seat can be readily adapted to swivel about the gun pintle point for following gun motion in azimuth. Reels would be added for each of the diagonal tiedown straps and a track provided at the ceiling. The movable seat would be swiveled by leg motion as the gun is swung in azimuth.

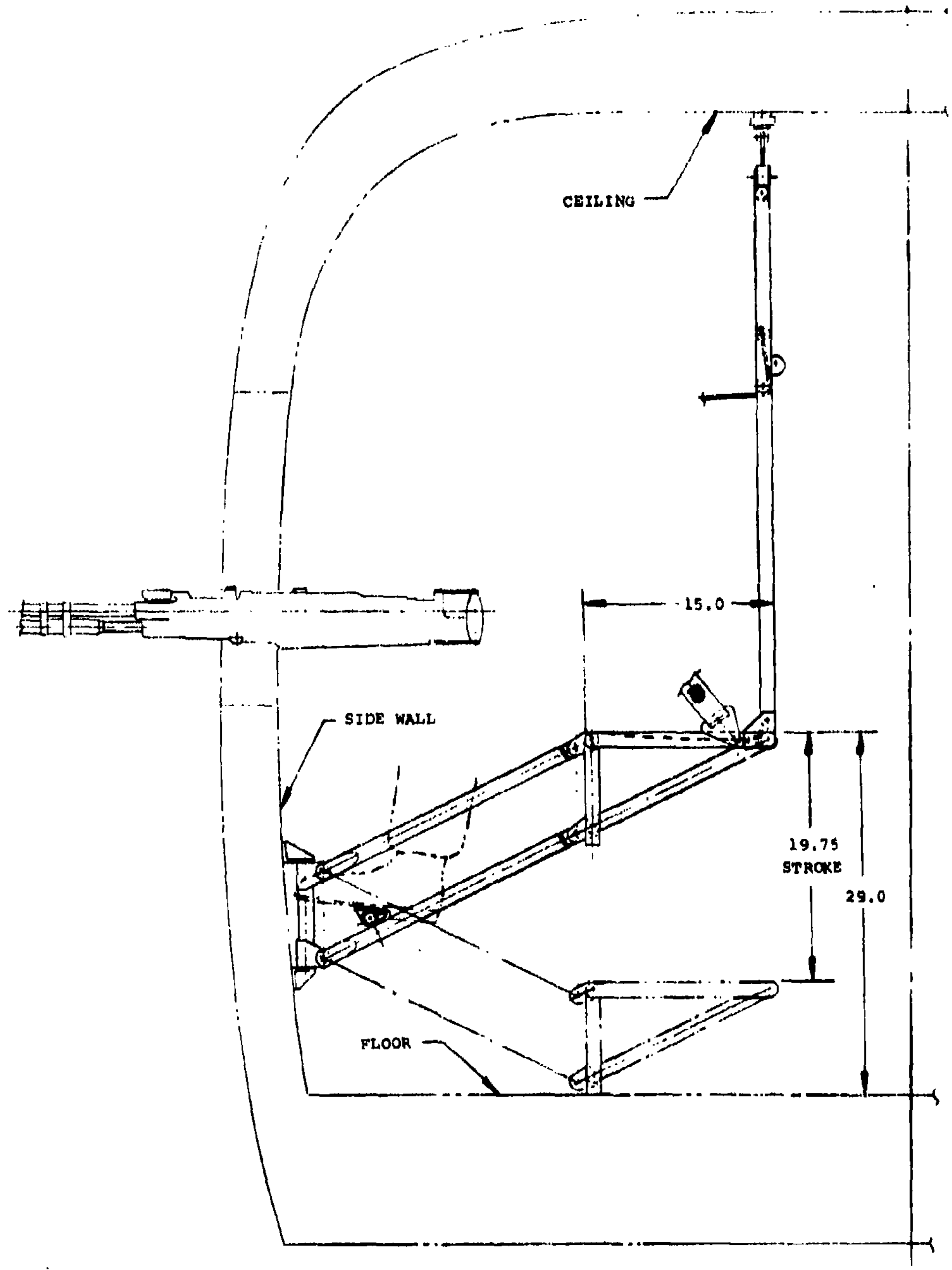


Figure 20. Concept D - Ceiling- and Wall-Mounted Fixed Unarmored Gunner's Seat (Sheet 1 of 2).

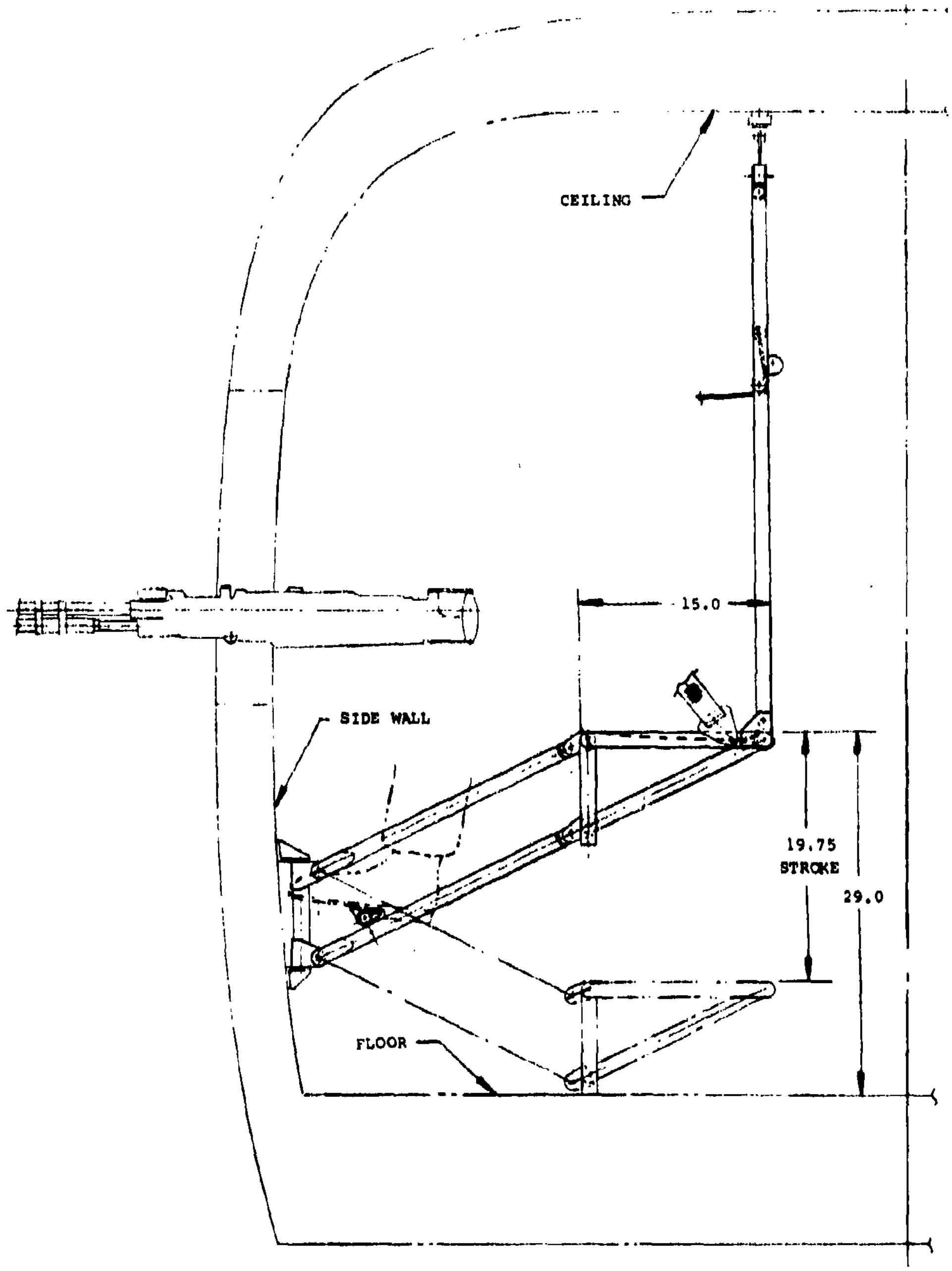


Figure 20. Concept D - Ceiling- and Wall-Mounted Fixed Unarmored Gunner's Seat (Sheet 1 of 2).

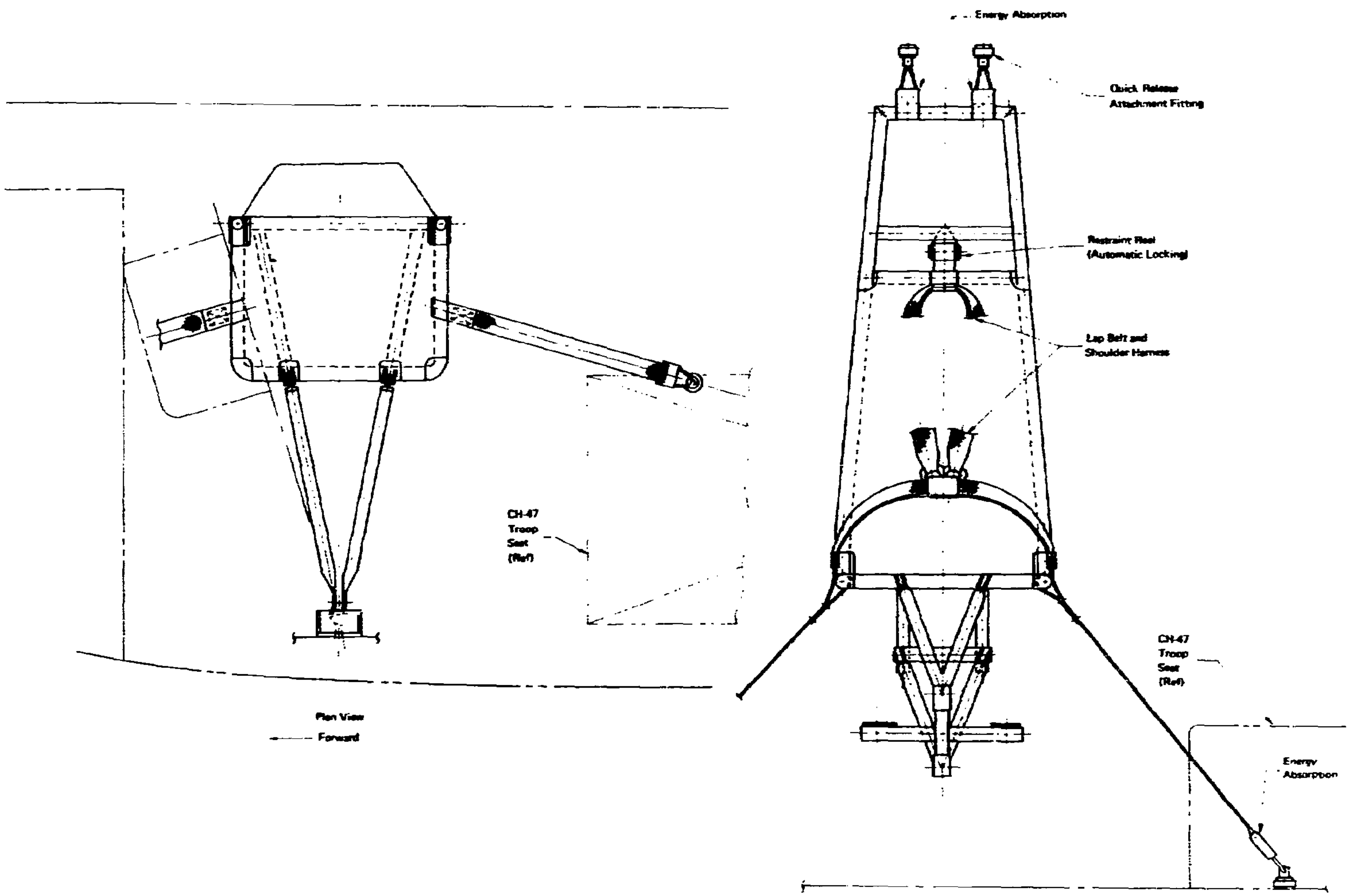


Figure 20. Concepc D - Ceiling- and Wall-Mounted Fixed Unarmored Gunner's Seat (Sheet 2 of 2).

The restraint system shown in Figure 15 is used with exception of the reels at the lap belt anchor points. Fixed anchors are provided because the limited gun motion requirement does not warrant reels. The shoulder harness reel is suspended from a tube in the seat back. An auxiliary tube guides the strap to the proper shoulder height.

Weight of the seat without the restraint system is 18.8 pounds. The restraint system weight, which includes one inertia reel, is 3.0 pounds.

Concept E--Concept E, shown in Figure 21, is a ceiling-mounted, side-facing seat stabilized at the floor and suspended from the ceiling by wire-bending energy attenuators. The seat pan is of tubular construction and is fabric covered. The pan is fully suspended from the ceiling by fabric and webbing sides and back. Legs are not needed under the seat to support the seat pan. Flexibility of the back aids in seat folding. A pocket is provided in the back for troops wearing combat assault packs. The pocket is covered for normal gunner use. Quick disconnect fittings attach the seat to the floor and ceiling.

Energy attenuation is provided in the vertical, forward, and lateral directions. In vertical impacts the wire-bending attenuators at the ceiling stroke, and the seat moves freely downward stabilized by the longitudinal diagonal struts. The seat pan height is 17 inches, which allows the seat to stroke vertically 15 inches. Forward impacts will cause the diagonal struts, which are telescoping-tube, torsion-wire, energy attenuators, to stroke. Stroking of the wire-bending attenuators at the ceiling will also occur. Lateral impacts will cause the seat to move frontward or backward as the annealed stainless steel diagonal cables yield at a predetermined load.

A fixed seat is used in this concept; therefore, to minimize gun butt travel in azimuth, an extension arm is attached between the gun and the pintle. The seat is 22 inches wide to permit the gunner's elbows to clear the seat sides. For extreme azimuth angles, his elbows will clear the sides because he must lean forward and to the side to maneuver the gun.

The restraint system shown in Figure 15 is used. The shoulder harness reel is attached to a tube suspended between the vertical seat support webbing. A second tube, similarly attached and below the reel support tube, serves to guide the inertia reel strap to the shoulder height position where it is connected to the double shoulder harness strap. Lap belt reels are mounted on both sides of the seat with the belt passing through slots in the seat sides.

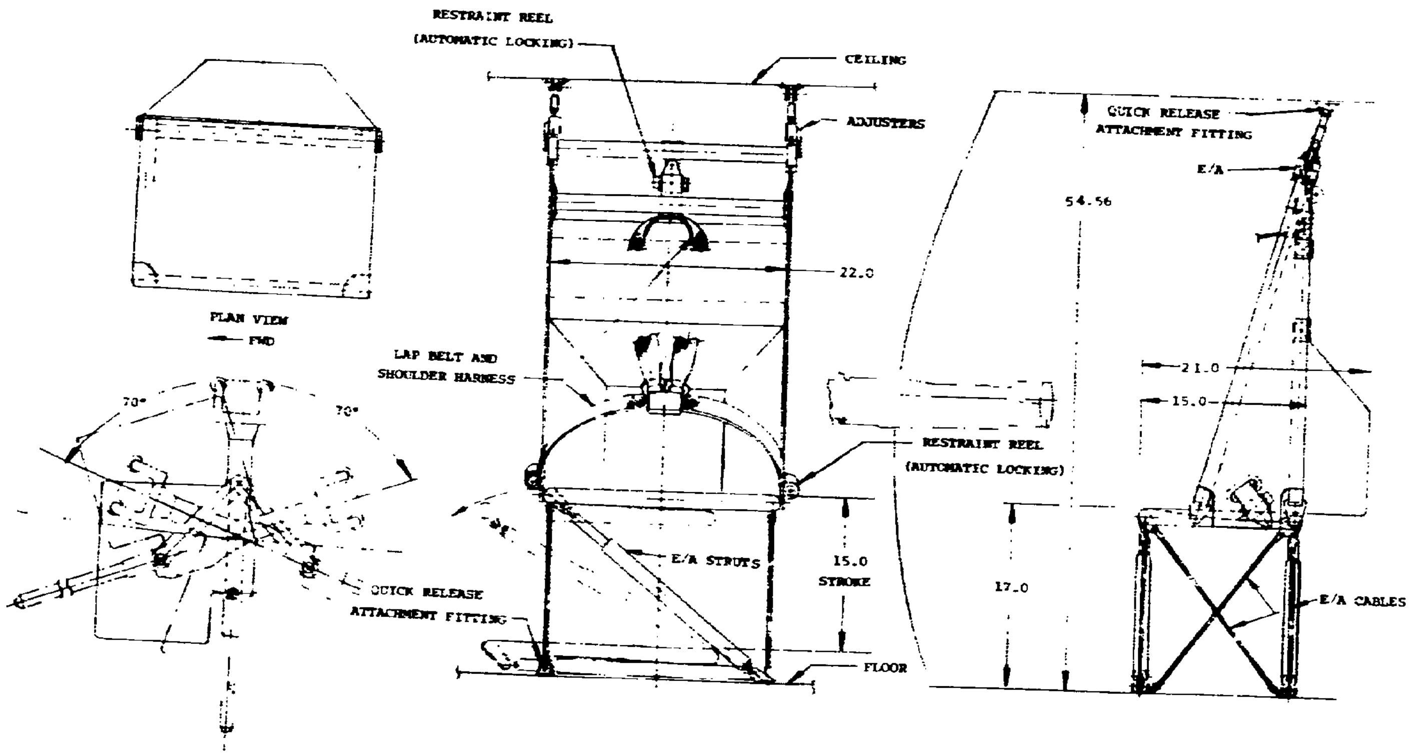


Figure 21. Concept E - Ceiling-Mounted Fixed Unarmored Gunner's Seat.

Weight of the seat without the restraint system is 10.7 pounds. The restraint system weight, which includes three inertia reels, is 3.0 pounds.

Concept E_1--Concept E_1, shown in Figure 22, is the same as Concept E with the exception of the suspension strap. Rather than supporting the seat pan with a straight strap, the side panel is designed as a catenary which holds the supporting strap in a curve and allows more clearance for lateral motion of the gunner. The weight of this concept is about the same as Concept E.

Integral-Armor Seats

Integral-armor seats have one-piece moulded buckets of ceramic tiles and fiberglass. Due to the inflexibility of the seats, cushions are provided on the seat pan and back. Seat cushions are tapered 6° for comfort and compress to 0.50-inch thick at the buttocks. The back cushion is a contoured pad approximately 1.0-inch thick.

Concept F--Concept F, shown in Figure 23, is a ceiling-mounted, side-facing integrally armored seat stabilized at the floor and suspended by wire-bending energy attenuators at the ceiling. The armored seat bucket is attached through two angle members to the energy attenuators. Sides of the bucket are cut out to provide maximum elbow clearance for maneuvering the gun. The 22-inch seat width is ample for troop or gunner gear. No provision is made in the bucket for a back pack; making such provision would be impractical and would increase the weight.

Energy attenuation is provided in the vertical, forward, and lateral directions. During vertical impacts, the wire-bending attenuators at the ceiling stroke and the seat moves freely downward stabilized by the longitudinal diagonal struts. The seat pan height is 17 inches, allowing the seat to stroke 15 inches. Forward impacts will cause the diagonal struts, which are telescoping-tube torsion-wire energy attenuators, to stroke. Stroking of the wire-bending energy attenuators at the ceiling will also occur. During lateral impacts, the seat will move frontward or backward as the annealed stainless-steel diagonal cables yield at a predetermined load.

A fixed seat is used in this concept; therefore, to minimize gun butt travel in azimuth, an extension arm is attached between the gun and the pintle. Overall travel of the gun butt is reduced from 36 to 22 inches in an arc of 140° (Figure 17).

The single-reel double-strap restraint system shown in Figure 15 is used. The shoulder harness reel is attached to the top of the seat back at the prescribed 26-inch height. Lap belt reels are mounted on both sides of the seat.

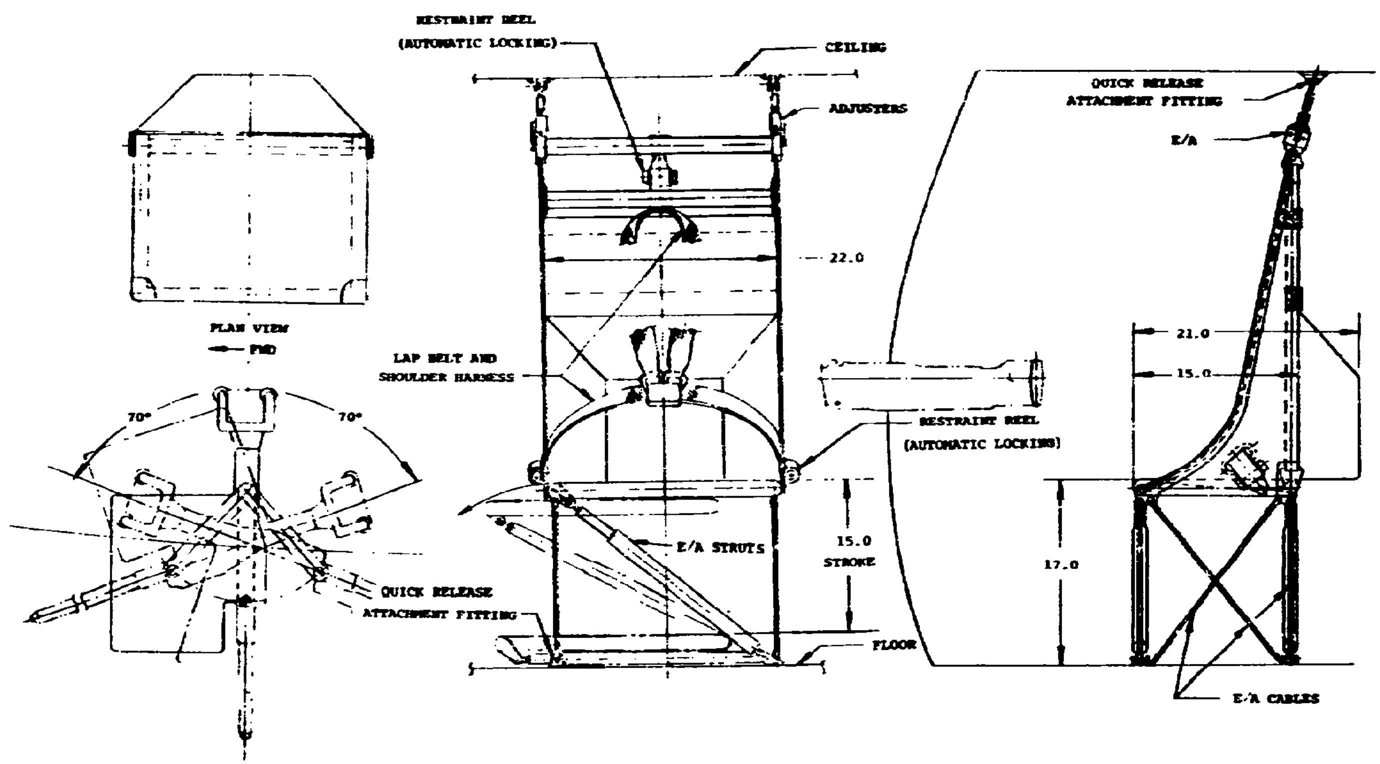


Figure 22. Concept E_1 - Ceiling-Mounted Fixed Unarmored Gunner's Seat.

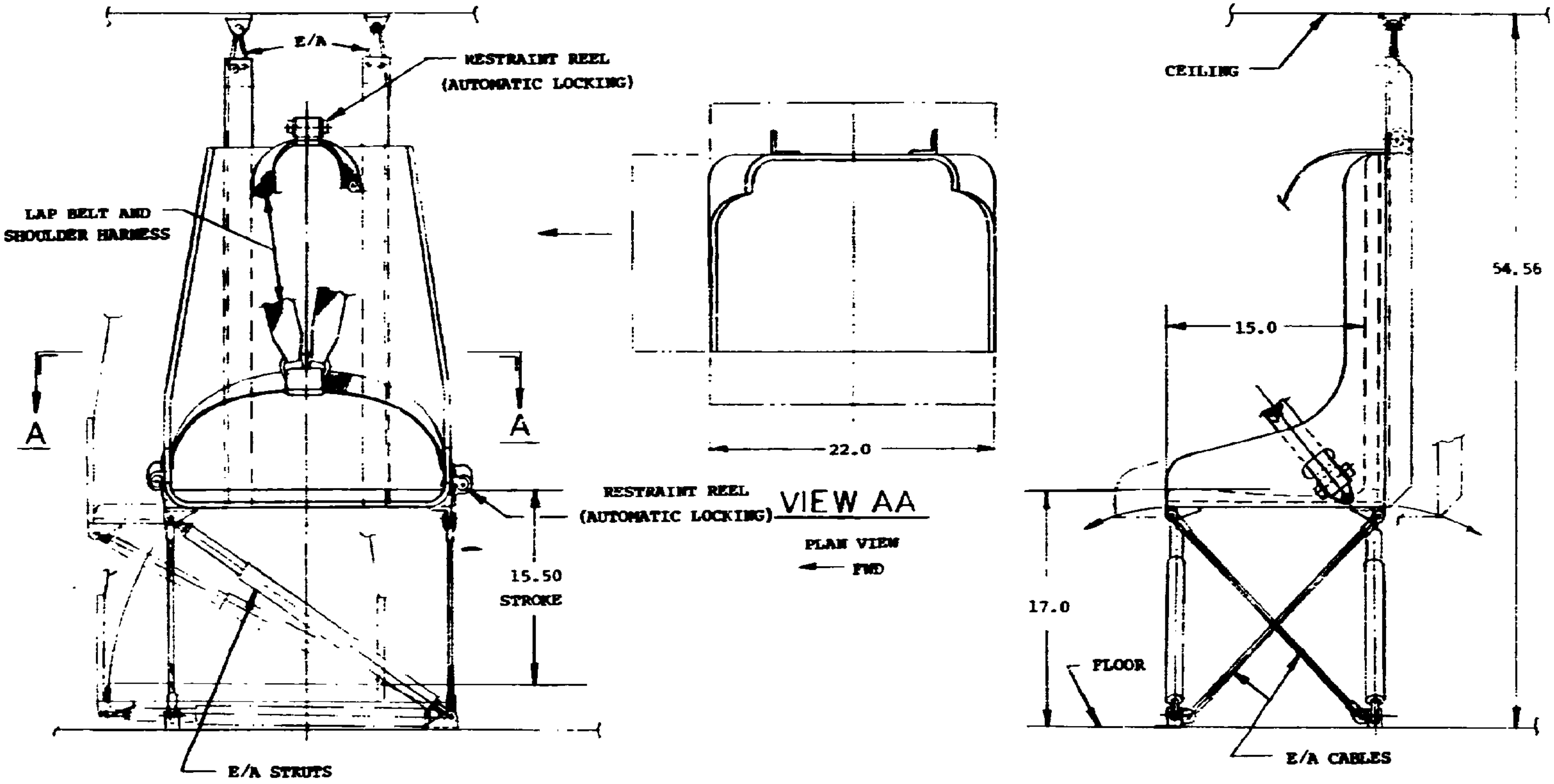


Figure 23. Concept F - Ceiling-Mounted Fixed Integral-Armor Gunner's Seat.

The seat weight is broken down as follows: bucket, 39 pounds; supports, 11.7 pounds; restraint system, including three reels, 3.0 pounds.

Concept G--Concept G, shown in Figure 24, is an integrally armored floor-mounted seat. It is mounted on a carriage which rolls on floor rails in the longitudinal direction. Forward and aft seat travel aids the gunner in maneuvering the gun in azimuth without having to get out of the seat. The armored bucket is the same as that of Concept F. Support of the bucket is through blocks at the top and bottom of the bucket which slide on a vertical support tube. Keyways on the tube prevent lateral rotation. Stabilization is by means of a lateral and longitudinal strut. A universal joint attaches the support tube to the carriage, which rolls on tracks. The stabilizing struts are also attached to the carriage.

Crash impact loads are attenuated in the vertical, forward, and lateral directions. Wire-bending attenuators attached from the top of the tube to the vertical slide blocks provide vertical attenuation. Lateral attenuation is achieved by the longitudinal and lateral diagonal struts. These struts are constructed of telescoping tubes with torus wire wound between them. Load limiting occurs as the strut strokes and the wire rolls. The universal joint at the base of the vertical support tube allows the seat to move freely in the direction of crash impact, and the seat is fully restrained against rebound at all times. The seat, with a 17-inch seat pan height, is capable of a 15.5-inch vertical stroke.

Seat operation consists of moving the seat longitudinally during azimuth motion of the gun. Manual or inertial locks can be provided to lock the seat to the track. Seat travel, space permitting, can be sufficient to permit use of a fixed-pintle-mount gun (Figure 24).

The single-reel double-strap restraint system shown in Figure 15 is used. The shoulder harness reel is attached to the top of the seat back top at the prescribed 26-inch height. Lap belt reels are not necessary due to the longitudinal seat motion capability.

The seat weight is as follows: bucket, 39 pounds; supports 44.4 pounds; restraint system, with one reel, 2.0 pounds.

Concept H--Concept H, shown in Figure 25, is a floor-mounted, side-facing integrally armored seat. This concept is similar to Concept G with the exceptions that it is fixed to the floor and the keyway preventing rotation has been removed to permit the seat to be rotated 90° to a forward-facing position. This feature is provided because human tolerance to impact accelerations is much greater in the forward-facing direction. The

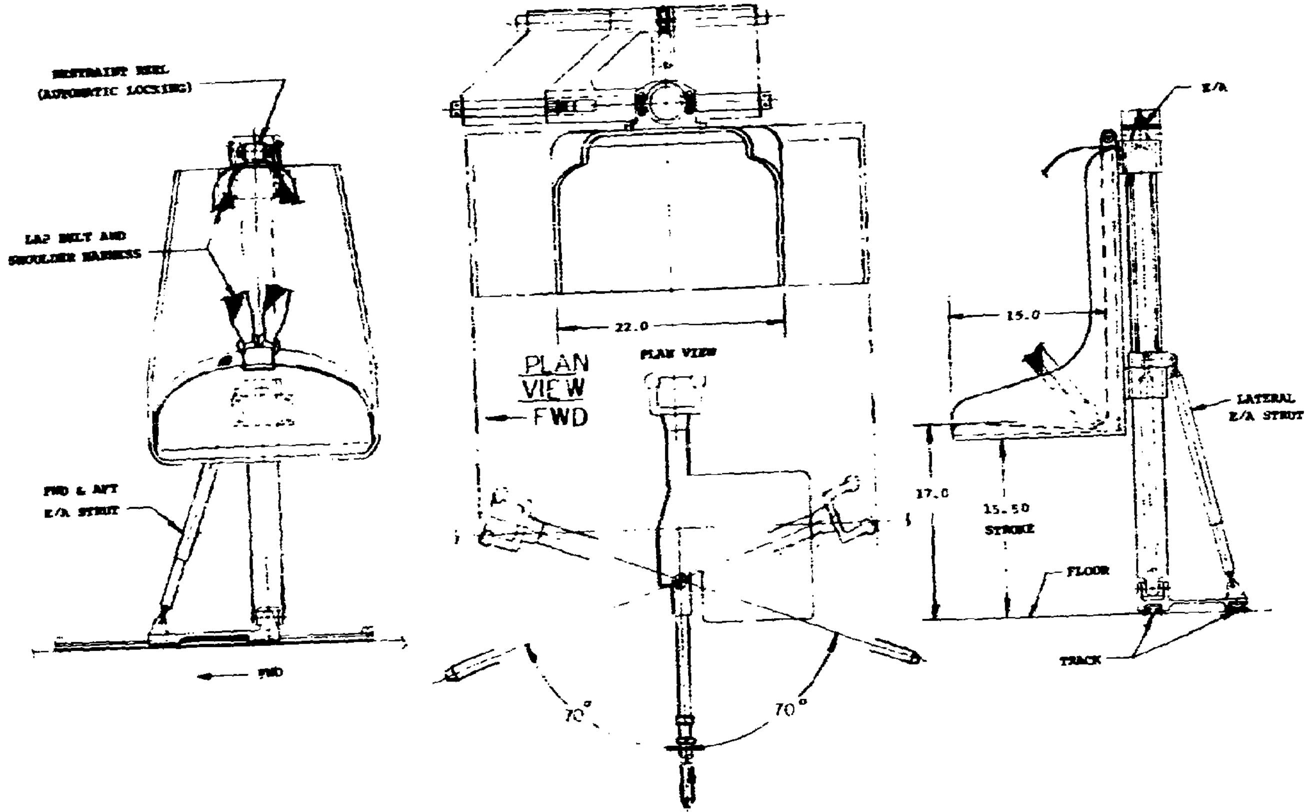


Figure 24. Concept G - Floor-Mounted Swiveling Integral-Armor Gunner's Seat.

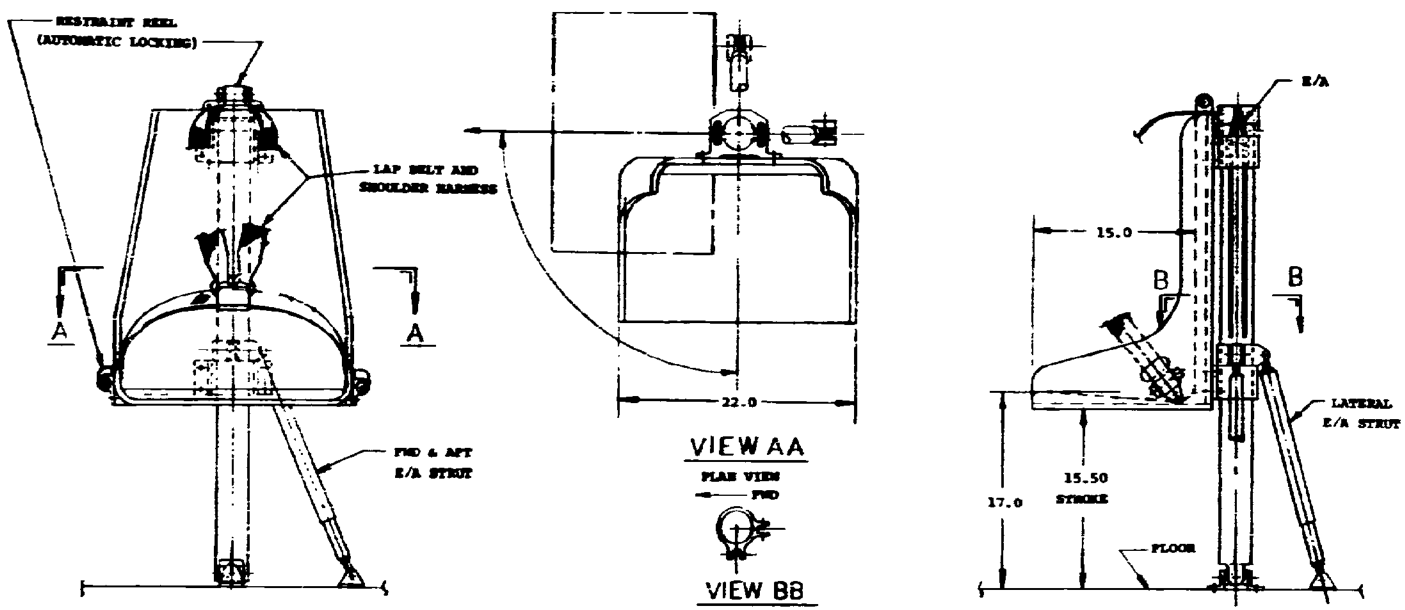


Figure 25. Concept H - Floor-Mounted Swiveling Integral-Armor Gunner's Seat.

gunner can face forward during takeoff and landing and when warned of an impending crash. The three-axis attenuation features of Concept G are included in this concept.

This is a fixed seat, and armored bucket sides minimize side motion; therefore, a movable gun pintle link (Figure 17) may be necessary. The single shoulder harness reel with double straps and double lap belt reels are used (Figure 15).

The seat weight is as follows: bucket, 39 pounds; supports, 31 pounds; restraint system, with three reels, 3.0 pounds.

Concept J--Concept J, shown in Figure 26, is a side-facing integrally armored ceiling- and floor-mounted seat. The armored bucket is the same as that used in the previous concepts. The bucket is supported by a stanchion tube running from floor to ceiling. Slide blocks on the tube are attached to the seat, and the seat is free to rotate 360° about the tube.

Energy attenuation is provided only in the vertical direction. A wire-bending attenuator, attached to the upper slip ring, strokes as the seat slides down the tube during vertical crash acceleration. The seat pan height of 17 inches allows a vertical stroke of 15.5 inches. The seat can be rotated to a forward-facing position for takeoff and landing, or when the gunner is warned of an impending crash. If the seat is not facing in the direction of impact, it will automatically rotate to that position. Design for lateral loading is unnecessary, and the occupant would never be subjected to accelerations in the lateral direction.

The seat in this concept is essentially fixed; therefore, a movable-link-mounted pintle point is recommended for gun installation to minimize gun butt travel.

The restraint system shown in Figure 15 is used including reels on each side of the seat bucket for the lap belt. A single reel is attached to the top of the seat bucket, and the double shoulder strap is attached to the reel in an inverted-Y arrangement.

The seat weight is as follows: bucket, 39 pounds; supports, 22.1 pounds; restraint system, with three reels, 3.0 pounds.

Concept K-- Concept K, shown in Figure 27, is a side-facing integrally armored ceiling- and floor-mounted seat. The armored bucket is the same as that used in the previous concepts. The bucket is supported at the bottom by an arm-mounted swivel. The arm is attached to a stanchion tube with slide blocks. Wire-bending energy attenuators are connected between the top slide block and a swivel ring mounted above it.

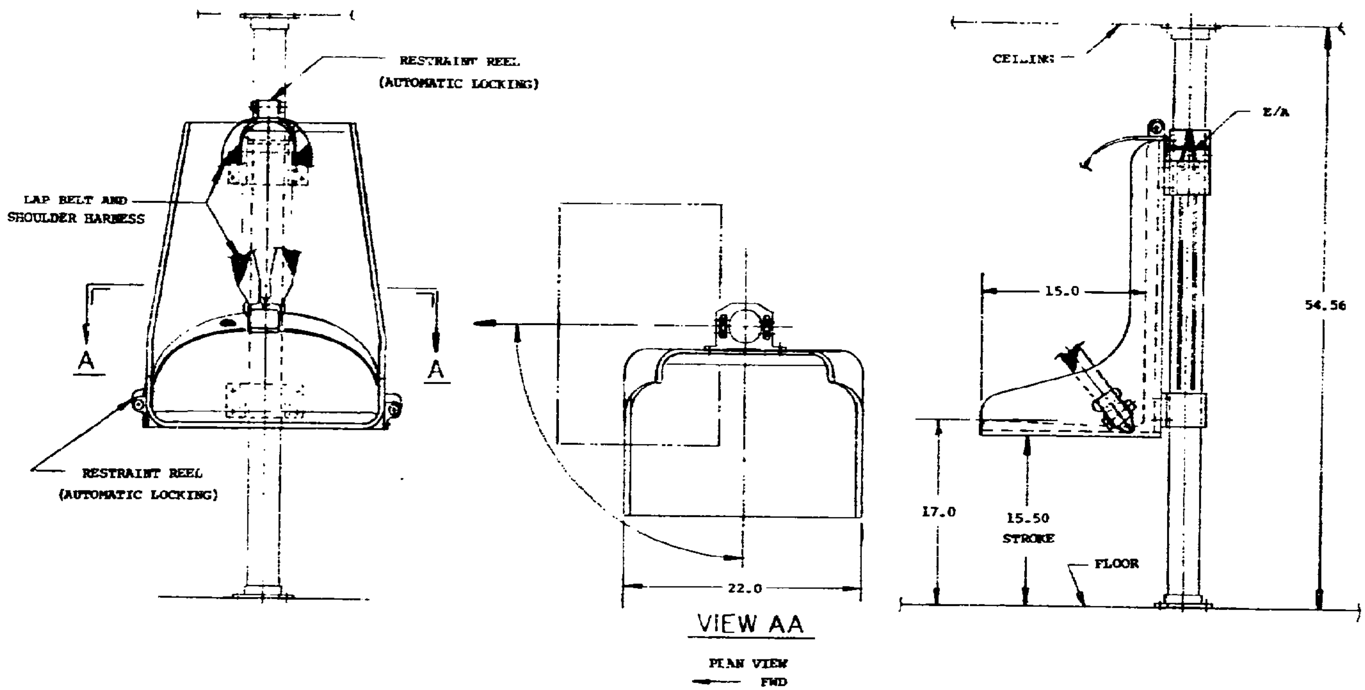


Figure 3̃. Concept J - Ceiling- and Floor-Mounted Swiveling Integral-Armor Gunner's Seat.

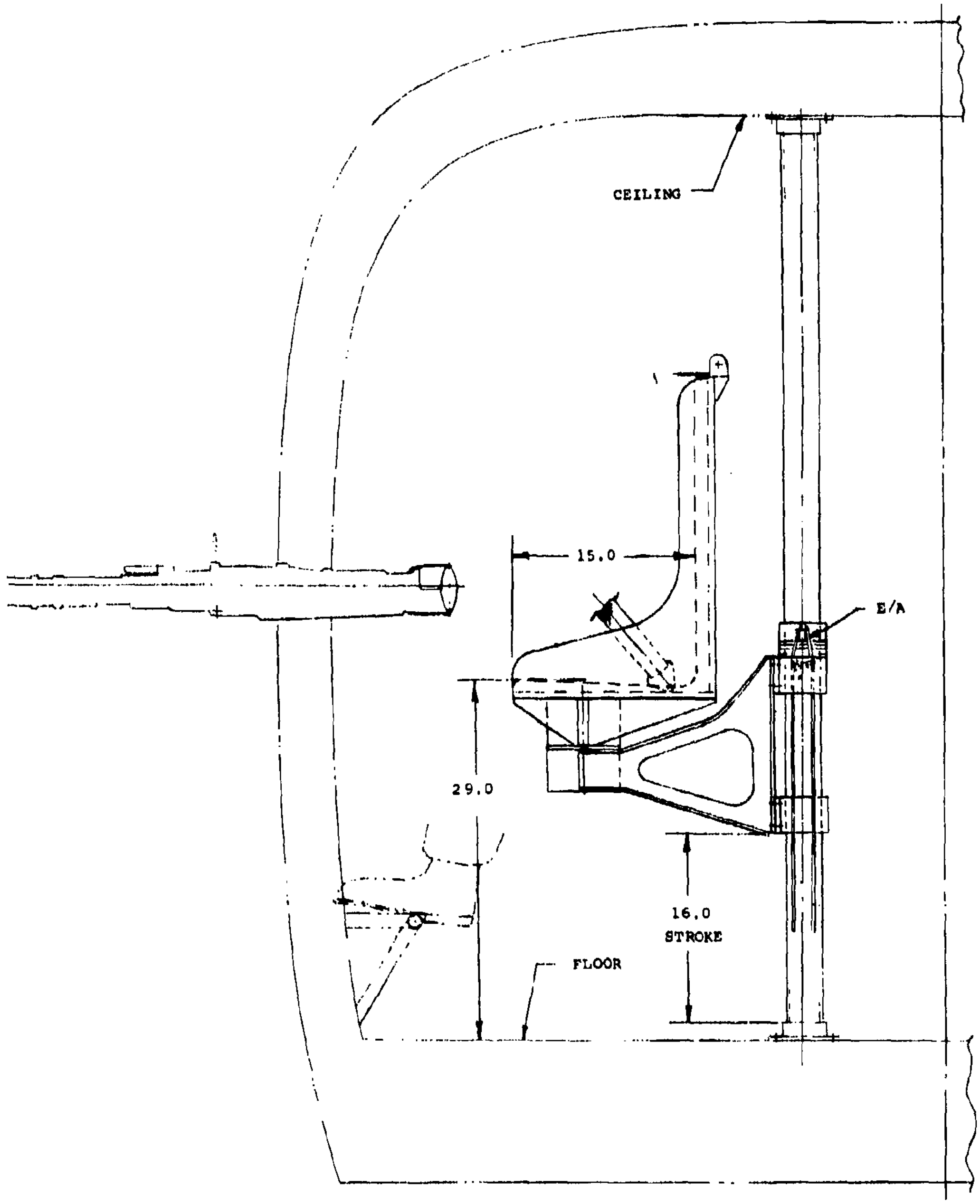


Figure 27. Concept K - Ceiling- and Floor-Mounted Movable Integral-Armor Gunner's Seat (Sheet 1 of 2).

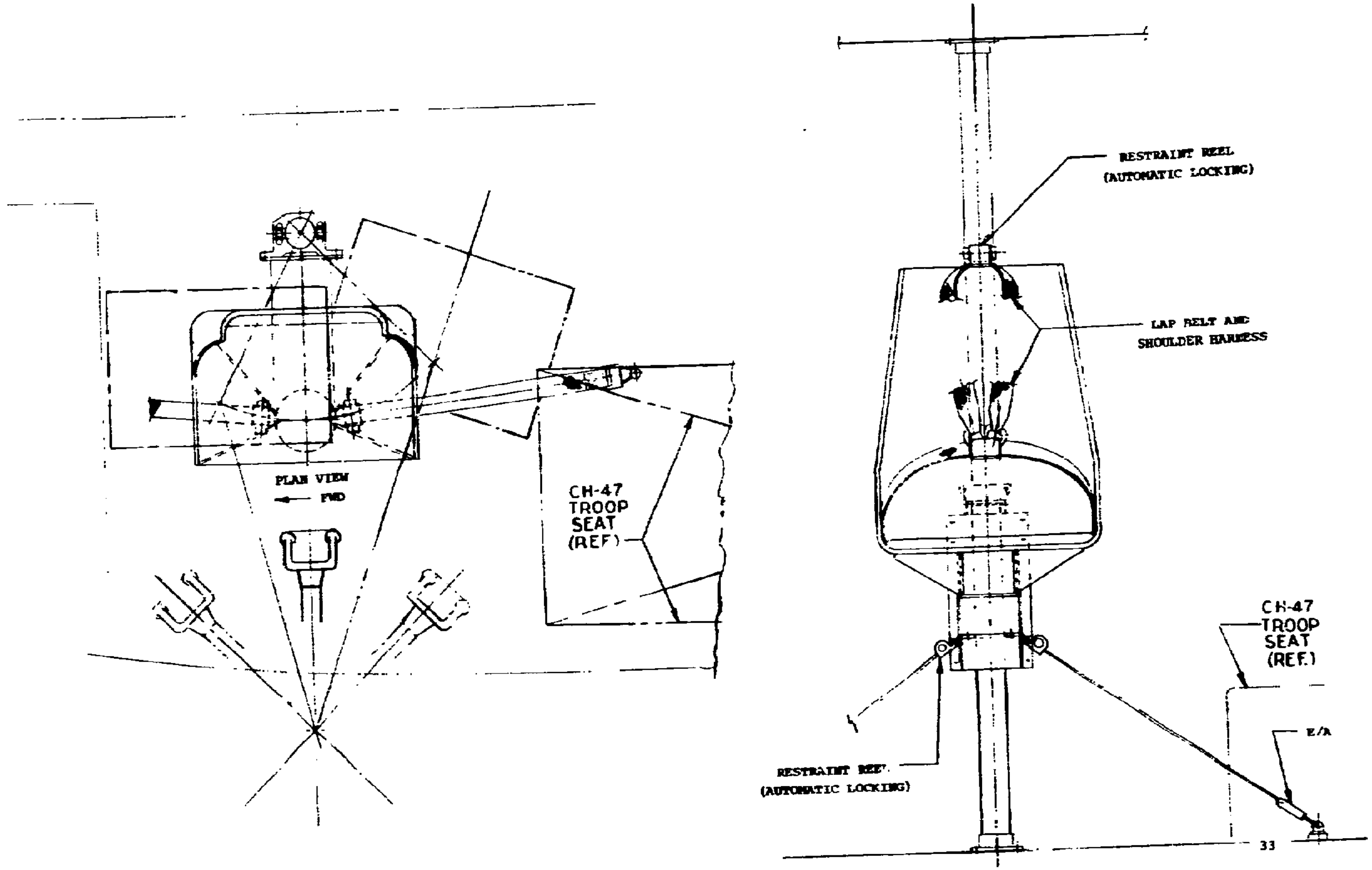


Figure 27. Concept K - Ceiling- and Floor-Mounted Movable Integral-Armor Gunner's Seat (Sheet 2 of 2).

Seat operation consists of swinging the seat from side to side as the gun is swung in azimuth. The seat not only moves sideways but can swivel to maintain alignment with the gun. A fixed-pintle gun mount is used in this concept due to seat motion capability. Side motion of the seat is unrestricted by using low-friction bearing joints. Motion is restricted during accelerations from flight loads or crash impacts by diagonal straps attached between the floor and automatically locking inertia reels on the seat base.

Energy attenuation is provided in the vertical and forward directions. During vertical impact the wire-bending attenuators attached to the slide blocks stroke as the seat slides down the tube. The seat is capable of 16 inches of vertical seat stroke. Bottoming occurs when the bottom slide block contacts the stanchion collar at the floor. Diagonal straps attached between the floor and the automatic locking inertia reel at the seat pan restrain the seat during longitudinal impact. Forward impact loads are attenuated by an energy attenuator at the floor attachment.

The restraint system shown in Figure 15 is used without the lap belt reels; seat motion capability makes the reels unnecessary. A single reel is attached to the top of the seat bucket, and the double shoulder straps are attached to the reel strap in an inverted-Y arrangement.

The seat weight is as follows: bucket, 39 pounds; supports, 36.7 pounds; restraint system, with one reel, 2.0 pounds.

Modular-Armor Seats

Modular-armor seats are essentially unarmored seats with armor plates attached. These seats must maintain integrity during crash impacts with or without the armor attached. Only essential armor has been added to these seats. Seat-bottom armor is considered most important; partial back armor, which overlaps back body armor, is second in importance.

Most of the previous seat concepts are adaptable to the modular armor design. Two of the unarmored seat concepts will be used as examples of modular armor attachment and its effect on seat weight.

Concept L--Concept L, shown in Figure 28, is similar to Concept E_1 with the exception that the pocket for the troop's combat assault pack has been removed. Ceramic armor plates have been added to the bottom of the seat pan and partial back armor added to the back with a supporting bracket. Structural members, although of the same configuration as Concept E_1, are strengthened to accept the added armor plate loads.

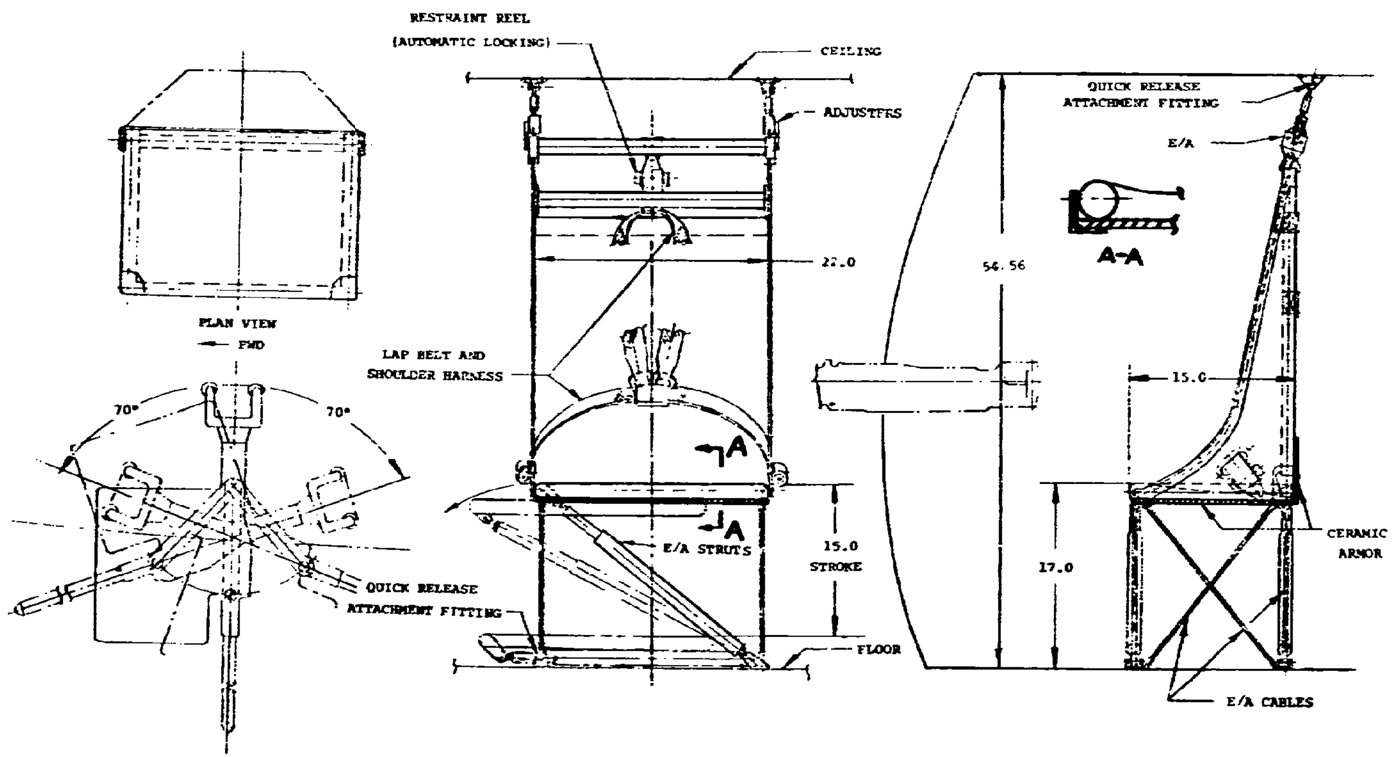


Figure 28. Concept L - Ceiling-Mounted Fixed Modular-Armor Gunner's Seat.

Weight of the seat is as follows: armor plate, 16.7 pounds; seat, 10.4 pounds; restraint system, including three inertia reels, 3.0 pounds.

Concept M--Concept M, shown in Figure 29, is similar to Concept A with the exception that the pocket for the troop's combat assault pack has been shortened in depth. Ceramic armor plates have been added to the bottom of the seat pan and partial back armor added to the back support tubes. Structural members of the seat are strengthened to accept the added armor plate loads.

The seat weight is as follows: armor plate, 15.3 pounds; seat, 10.7 pounds; restraint system, including three inertia reels, 3.0 pounds.

OCCUPANT CRASH HAZARDS ANALYSIS

An occupant crash hazards analysis applicable to each of the seat concepts was made. An optimum force-deflection curve for the vertical energy attenuators was determined by the use of mathematical simulation. A similar wire-bending energy attenuator was used for all of the seat concepts, differing only in the diameter of the wire used to accommodate the various seat weights. The optimum force-deflection curve was arrived at by using the weight of the lightest seat concept. The curve is applicable to all the seat concepts by increasing the curve force proportional to the seat weight. Crashworthiness evaluation of the concepts was based principally on the geometry of the attenuation system installation and seat stability during stroking. The vertical energy attenuating device did not influence the evaluation because the same device is used on all seats.

Mathematical Simulation

An analysis was made to predict the statistical probability of spinal injury during the crash environment specified in the draft crashworthy gunner seat specification. The dynamic response index (DRI) program developed during the USAAMRDL crashworthy troop seat investigation was used to evaluate various energy attenuator force-deflection curves. Problems of sensitivity previously experienced with notched force-deflection curves for lightweight seats prompted the use of trapezoidal curves for the unarmored gunner's seats. Notched curves are not suitable for lightweight seats but are more suitable for heavy, armored seats because the mass of the heavier seat and the occupant do not act together in a dynamic situation. This results in the attenuator not functioning if it is sized for the combined mass. A reduction in force is necessary during the time that the seat and occupant

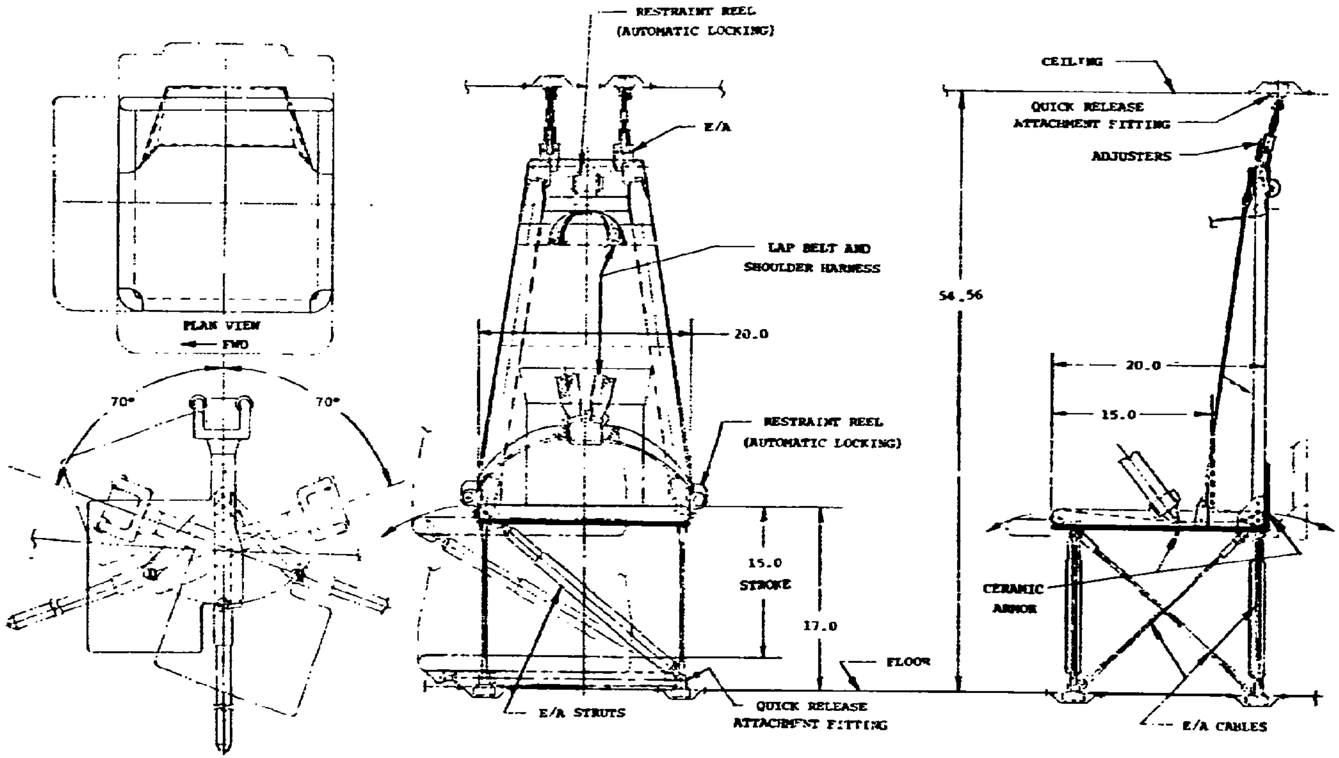


Figure 29. Concept M - Ceiling-Mounted Fixed Modular-Armor Gunner's Seat.

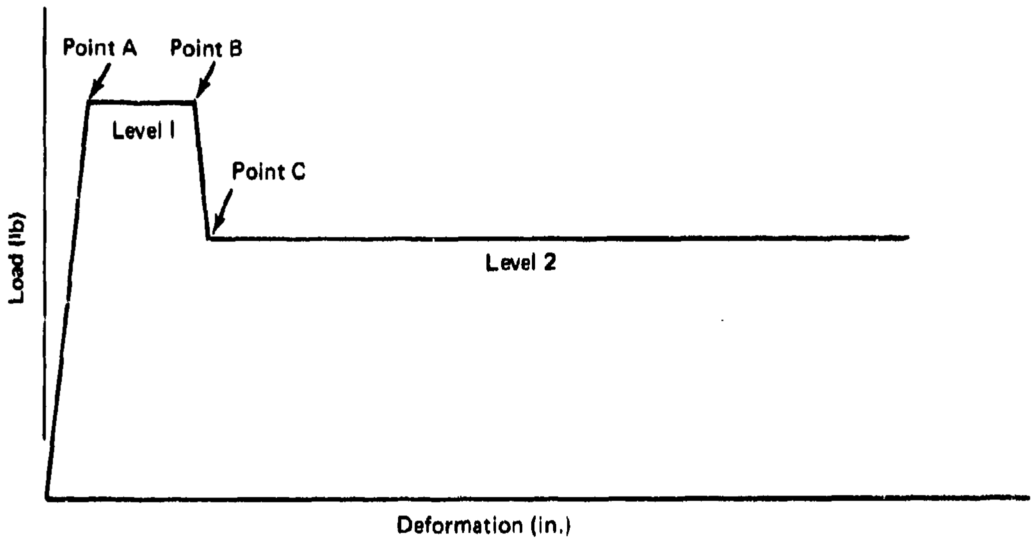
are not acting together; it is achieved by a notch in the force-deflection curve. Wire-bending attenuators with variable-diameter wire can produce the notched force effect. Placement of the notch in the force-deflection curve is critical and is dependent upon the relationship of seat weight and occupant-with-equipment weight. The wide range of weights experienced for troops and gunners with and without equipment does not permit use of a notch curve because the reduction in force produced by the notch will not coincide with the accelerated mass of a lightly equipped occupant if the notch was established for a heavily equipped occupant. The notch, of necessity, is narrow and will not accommodate the weight range. Excessive stroking occurs if the combined mass acts during the notch period. A trapezoidal force-deflection curve is preferable for wide weight range applications.

Wire-bending attenuators with constant wire diameter are used in all the unarmored gunner's seat concepts. Typical trapezoidal force-deflection curves produced by this type of attenuator are shown in Figure 30. Twenty-two computer runs were made at various force levels (Table 3). Each force-deflection curve was analyzed at two impact velocities: 42 fps, the 95th-percentile impact velocity, and 36.8 fps, the velocity the fuselage is reduced to in a 42-fps impact by a 20-fps landing gear.

Results of the computer runs show a very stable and predictable progression in the reduction of seat stroke and increase in DRI as the force is increased. A DRI of 19 was set as the goal for the 50th-percentile man and was reached in runs 17 through 22 (Table 3). A DRI of 19 represents the 5-percent probability of spinal injury after adding one DRI for force tolerance (which is allowed on ejection seats for catapult grain and temperature effects). This figure is conservative for energy attenuating seat use because its level was reached for a very short duration of time (less than 0.005 second in runs 19 and 20), as compared to the longer duration of ejection seat acceleration.

Seat strokes of 10.5 inches and 13.5 inches occurred in runs 21 and 22 for 36.8- and 42-fps impacts respectively. This allows 4.5 to 1.5 inches of stroke for the 95th-percentile occupant using the 15-inch seat stroke, which is the least stroke available in some concepts.

Computer runs were not made for the 5th- and 95th-percentile occupant because the dampening and stiffness coefficient in the computer math model is for a 50th-percentile man and cannot effectively be used for other weights. If the DRI of 19 is maintained for the 50th percentile, the range of 5th through 95th should not exceed the 5-percent probability of spinal injury.



Curve	Point A	Point B	Point C	Level 1	Level 2
1	0.5	1.0	1.5	3000	2430
2	0.5		1.5	3200	2500
3	0.5	1.0	1.5	2800	2600
4	0.5	1.0	1.5	3000	2700
5	0.5	1.0	1.5	3000	2800
6	0.5	1.0	1.5	3100	2900
7	0.5	1.0	1.5	3300	3000
8	0.5	1.0	1.5	3800	3200
9	0.5	1.0	1.5	3800	3300
10	0.5	1.0	1.5	3800	3250
11	0.5	1.0	1.5	4000	3250

Figure 30. Summary of Similar Force-Deflection Curves.

TABLE 3. COMPUTER RUN RESULTS FOR DRI AND STROKE							
Run No.	FPS	Max Stroke	Time	DRI at Max Stroke	Max DRI	Time at Max DRI	Curve No.
1	42	22.5	0.140	9.6	13.9	0.070	1
2	36.8	17.4	0.120	10.0	13.9	0.070	1
3	42	20.6	0.130	11.0	14.6	0.075	2
4	36.8	16.1	0.115	11.8	14.6	0.075	2
5	36.8	16.2	0.110	12.9	15.0	0.075	3
6	42	20.6	0.125	11.9	15.0	0.075	3
7	42	19.0	0.120	12.5	15.7	0.075	4
8	36.8	14.9	0.105	13.7	15.7	0.075	4
9	36.8	14.3	0.105	14.3	16.3	0.075	5
10	42	18.1	0.115	13.4	16.3	0.075	5
11	42	17.2	0.11	14.4	16.8	0.075	6
12	36.8	13.5	0.10	15.3	16.8	0.075	6
13	36.8	12.7	0.95	16.4	17.4	0.075	7
14	42	16.2	0.11	14.9	17.4	0.075	7
15	42	14.1	0.10	16.9	18.7	0.075	8
16	36.8	11.0	0.09	17.9	18.7	0.075	8
17	36.8	10.6	0.09	18.5	19.2	0.075	9
18	42	13.6	0.10	17.5	19.2	0.075	9
19	42	13.8	0.10	17.2	19.0	0.075	10
20	36.8	10.8	0.09	18.2	19.0	0.075	10
21	36.8	10.5	0.09	18.2	19.0	0.075	11
22	42	13.5	0.10	17.2	19.0	0.080	11

All runs conducted with 50th-percentile man

Crashworthiness Evaluation

Each seat concept was evaluated for the degree of seat motion freedom, energy attenuation capability, orientation in the direction of highest human tolerance to impact accelerations, stabilization during and after stroking, and linear guidance during stroking.

All seat concepts do not provide freedom of motion during stroking to the same degree, and some do not provide 3-axis attenuation. Due to the manner in which the seats are stabilized or guided during vertical impact, motion in the horizontal directions may be restricted or prevented. Vertical motion in some concepts may be restricted to various degrees by the stabilizing methods. The degree of restriction of linear motion in each axis is evaluated and rated on a basis of 0 to 5, with 5 being unrestricted and 0 being completely restricted (Table 4).

Forward- or aft-facing seats provide greater crashworthiness protection than side-facing seats due to the lower human tolerance to acceleration in lateral direction. Therefore, seats capable of rotation from the side-facing gunnery-operation position to a forward- or aft-facing position receive a higher human tolerance rating than fixed side-facing seats. Fixed side-facing seats with sides provide better restraint than open-sided seats. For this reason seat concepts with sides were given a higher human tolerance rating than open-sided seats (Table 4).

Seat concepts using a tubular guide for vertical stroking were given the highest rating for stabilization and guidance during and after stroking. When a radius rod or cable is used for guidance and stabilization, the stroking path is altered from a straight line to an arc, and concepts with this feature received lower guidance ratings. Cables and straps used for seat stabilization go slack after stroking, thus reducing seat stabilization; they therefore received lower ratings (Table 4).

The evaluation factors were weighted relative to their importance. Human tolerance, being most important, received scores from 1 to 10. Other factors were scored 1 to 5. Freedoms of motion in the three planes were averaged and entered as a single item (Table 4).

HUMAN ENGINEERING ANALYSIS

Each seat concept was reviewed to evaluate the gunner's ability to perform his duties unencumbered by seat system configuration and to determine the configuration's compatibility with clothed and equipped gunners and troops. Visibility and field of fire

TABLE 4. CRASHWORTHINESS EVALUATION									
	Seat Motion Freedom				3-Axis Attenu-ation	Restraint	Human Toler-ance	Guidance and Stabili-zation	Total
Concept	Vert	Fwd	Side	Total					
A	4	4	4	4.0	5	5	2	3	19
B	4	4	4	4.0	5	5	2	3	19
C	4	4	4	4.0	5	5	10	3	27
D	4	4	0	2.7	3	5	2	3	15.7
E	4	4	4	4.0	5	2	4	3	18
E_1	4	4	4	4.0	5	2	3	3	17
F	4	4	4	4.0	5	5	3	3	20
G	5	4	4	4.3	5	5	3	5	22.3
H	5	4	4	4.3	5	5	10	5	29.3
J	5	3	0	2.7	2	5	10	5	24.7
K	5	4	0	3.0	3	5	8	4	23
L	4	4	4	4.0	5	2	3	3	17
M	4	4	4	4.0	5	5	2	3	19

Concept letter I omitted to avoid confusion with 1

were evaluated considering the mix of movable and nonmovable seats and pintle mounts.

Encumbrances

The manner in which the gunner seat pan is supported determines the primary degree of seat encumbrance. Stabilizing devices outside the seat planform would cause some encumbrance for ingress and egress but not necessarily for operation of the gun.

Seat pans supported behind the 15-inch depth do not encumber the gunner's motion. Seats with sides, such as the armored bucket seats, encumber gunner's sideward motion. Supports or suspension members from the ceiling to the sides of the seat pan in the seating area also encumber the gunner.

Seat stabilizing devices in the front of the seat would cause some encumbrance for operation of the gun as well as for ingress and egress. Stabilizers to the sides of the seat would not necessarily encumber gun operation, but would encumber ingress and egress.

As discussed in the section on design considerations, some encumbrance may have to be accepted to provide the best crashworthy features. A trade-off of encumbrance with crashworthiness and other features is made later in the comparative analyses section. Each concept is evaluated for degree of encumbrance with ratings made on the basis of 1 through 5, with 5 being no encumbrance and 1 unacceptable encumbrance (Table 5).

Equipment Compatibility

Seat width and depth are evaluated to determine compatibility with gunner equipment and with troop combat assault equipment. Seats without sides will accommodate the occupant's equipment either within the width of the seat or by allowing it to hang over. Seats with sides provide 20- to 22-inch inside widths which are adequate to accommodate 95th-percentile occupants in arctic clothing with survival vests or combat equipment.

A 15-inch-deep seating surface is provided on all concepts and is adequate for troop and gunner use. A minimum extension of 6 inches, in the form of a pocket on all nonarmored seats, will adequately accommodate combat assault packs worn by troops. Armored seats have no accommodations for combat packs due to the excessive weight and space required for the additional armor. These seats are rated lower for accommodation (Table 5).

Gunner Motion Requirements

Gunner motion requirements vary depending on the type helicopter, as previously discussed. Seat configuration will also vary to accommodate high and low window openings and high and low ceiling heights. To evaluate field of fire and visibility for each set concept, the type of aircraft and seat should be considered. However, for purposes of this evaluation all seats will be compared with each other. A seat receiving a low field-of-fire score will not necessarily be ruled out in the final comparative analysis if that seat is only to be used on an aircraft requiring a narrow angle of fire. Also, a movable gun pintle arm may provide the needed field of fire when using a fixed seat.

All of the seat concepts can be categorized into three types: those providing longitudinal motion, those providing rotary motion, and those that are fixed. The fixed and rotary motion seats do not aid the gunner in maneuvering; therefore, only the seats with longitudinal motion can be scored for their degree of motion. Seats which swing about the gun pintle point are given the highest rating of 5; seats on longitudinal tracks are rated 4, and seats rotating on pivots behind the seats are rated 3. Fixed seats are rated 1 even though the restraint system permits motion away from the seat (Table 5).

TABLE 5. HUMAN ENGINEERING EVALUATION

Seat Concept	Seat Pan Encum-brance	External Encum-brance	Troop Accommo-dation	Seat Motion	Comfort	Total Average Score
A	5	5	5	1	5	4.2
B	5	5	5	5	5	5.0
C	5	5	5	1	5	4.2
D	5	3	5	1	2	3.2
E	3	5	5	1	3	3.4
E_1	4	5	5	1	3	3.6
F	4	5	1	1	3	2.8
G	4	5	1	4	3	3.4
H	4	5	1	1	3	2.8
J	4	5	1	1	3	2.8
K	4	4	1	3	3	3.0
L	4	5	1	1	3	2.8
M	5	5	1	1	5	3.4

None of the seat concepts move vertically; therefore, vertical motion is not evaluated. Aircraft which require high depression angles, such as the UTTAS (70°), have low ceilings which do not permit vertical seat motion. Those with high ceilings, such as CH-47, require only a 45° depression angle, which can be achieved from a fixed seated position.

Comfort

Each concept was evaluated for occupant comfort. Seats with an auxiliary back having an angular slope in relation to the seat pan were given the highest rating. Straight-backed seats with cushions received average scores, and straight-backed seats with tubular frames covered with fabric received lower scores.

OPERATIONAL SUITABILITY ANALYSIS

Items considered under operational suitability include reliability, maintainability, weight, and cost.

Reliability

All gunner's seat concepts presented fall into two general categories, the rugged and the not so rugged. The not-so-rugged seats are constructed of fabric, webbing and tubing. These seats are more subject to wear than the rugged seats. Integrally armored seats fall into the rugged category. These seats are more sturdily constructed to carry the armor loads. Seats in this category would in general be more reliable than those in the first category. Seats within each of these categories range from more or less reliable, relative to each other, depending on the degree of mechanization. Fixed seats are more reliable than movable seats, and movable seats that swing on an arm are more reliable than seats that move in tracks.

Using the above considerations, each seat is evaluated for reliability relative to the others. A score of 5 is given for seats which are the most rugged and have the least mechanization. A score of 1 indicates the seat which is least rugged and has the most mechanization (Table 6).

Maintainability

Relatively little maintenance would be required on any of the seat concepts presented. Ceiling-suspended and floor-stabilized unarmored seats will require occasional tensioning to maintain taughtness. Turnbuckles are provided in the toggle release latches at the ceiling to remove any seat slack which develops. Fabric seat pans are attached with screws which can be removed

TABLE 6. RELIABILITY/MAINTAINABILITY EVALUATION

Concept	Fixed Seat	No Tracks	No Locks	No Guides	Rugged	Simple Stabilization	No Adjusters	One Reel	Total
A	X	X	X	X		X			5
B				X		X		X	3
C	X		X	X		X			4
D	X	X	X	X			X		5
E	X	X	X	X		X			5
E_1	X	X	X	X		X			5
F	X	X	X	X		X			5
G					X	X	X	X	4
H	X				X	X	X		4
J	X				X	X	X		4
K					X		X	X	3
L	X	X	X	X		X			5
M	X	X	X	X		X			5

to readjust or replace fabric. Energy attenuators are simple wire-bending or torsion-wire devices which require no maintenance. Armored seats which slide on tubes or keyways have permanent lubriplated surfaces and require no further lubrication. The seat which swivels during gunnery operation (Concept K) requires lubrication at major maintenance cycles. Track-mounted seats use permanently lubricated ball bearing rollers and require no further lubrication. Rod-end bearings at the ends of energy attenuating struts are permanently lubricated, sealed units requiring no maintenance.

Weight

Weight comparisons between the three types of seats should not be made because of the large difference in weight caused by the armor. Weight comparisons are made within each category and are listed in Table 7.

TABLE 7. WEIGHT COMPARISONS

Unarmored		Integral Armor		Modular Armor	
Concept	Weight	Concept	Weight	Concept	Weight
A	13.4	F	53.7	L	29.0
B	30.4	G	85.4	M	30.0
C	19.8	H	73.0		
D	21.8	J	64.1		
E	13.7	K	77.7		
E_1	13.7				

Cost and Simplicity

The principal differences in cost are due to the amount of armor used. The unarmored seats are, in general, the least costly and the integral-armor seat is the most costly. Cost will be evaluated within each seat category. Each concept was evaluated for simplicity and is discussed in the comparative analysis.

COMPARATIVE ANALYSIS

Designs for each of the three types of gunner's seats are compared for the purpose of selecting the best overall design in each category. Of the 13 concepts presented, many combinations are feasible. Features shown on one concept could be adapted to other concepts depending on the type of aircraft, space available, operational requirements, need for armor, and acceptable weight and cost penalties.

Unarmored Seats

Six unarmored seat concepts have been presented. Of these, four are fixed, one is horizontally movable (swinging in an arc about the gun pintle), and one swivels about its centerline. Concepts A, B and C are variations of the selected crashworthy troop seat concept developed by USAAMRDL. These seats have no side obstructions in the 15-inch seating area but require a minimum depth of 20 inches to support their cantilevered seat pans. Concepts E and E_1 are similar and have a simple, lightweight, seat pan suspension system consisting of fabric and webbing. Sides are needed to support the seat pan which may contribute some encumbrance to sideward motion of the gunner in a fixed seat. The degree of encumbrance, if any, will have to be determined by mockup. The principal advantages of concepts E and E_1 are simplicity and shallow seat depth. Structure behind the seating area is not required to support the seat pan. Concept D employs a simple fabric and webbing seat pan suspension at the back, but requires a pantograph to support the pan at the front. Sides of the seat are clear of encumbrances. This concept is suitable for aircraft with high ceilings and high pintle mounts.

In selecting the best of these six concepts, we must consider human factors, crashworthiness, reliability, maintainability, simplicity, cost and weight. Although it was not evaluated, the adaptability of the seat to a specific aircraft type will be an important consideration in the final seat selection.

The selection factors tend to work in opposition to each other; therefore, compromises and trade-offs are necessary for the selection of an optimum seat. Seat concepts which offer the most crashworthiness tend to restrict gunner operations, and seats with the most freedom of motion for the gunner are the most costly.

Higher values are given to the more important factors in the seat concept comparative analysis. Of the five factors analyzed, crashworthiness and human factors (including gunner motion) were weighted because of their prime importance (Table 8).

Concept C received the highest score of the six unarmored seats. The principal feature of this concept is that it swivels to face forward or aft for better crashworthiness. Concept A, which received the second highest score, is similar to C but is a fixed seat. Concept B, which received the highest score for human factors, received a low overall score because the track system increased weight and cost and reduced reliability. Concept C also has a track system, but the increased crashworthiness outweighed the problems associated with tracks. Concept D received the lowest rating because of

TABLE 8. COMPARATIVE ANALYSIS

Concept	Human Factors	Crash-worthiness	Reliability Maintainability	Cost and Simplicity	Weight	Total
Unarmored						
A	8.4	19	5	4	5	41.4
B	10.0	19	3	3	1	36
C	8.4	27	4	3	3	45.4
D	6.2	15.7	4	4	3	32.9
E	6.8	18	5	5	5	39.8
E_1	7.2	17	5	5	5	39.2
Integral Armor						
F	5.6	20	5	5	5	40.6
G	6.8	22.3	4	2	1	36.1
H	5.6	29.3	4	3	4	45.9
J	5.6	24.7	4	4	3	41.3
K	6.0	23	3	1	2	35
Modular Armor						
Same as unarmored and integral-armor evaluation						

the lack of lateral attenuation, external encumbrances, and weight.

Concept C is selected as the best of the unarmored seats. This analysis shows that the best crashworthy seat can be obtained without penalizing gunner operations and without excessive weight and cost. The unarmored seat recommended is an adaptation of the USAAMRDL troop seat mounted on a swiveling base. Use of this concept would simplify logistics and reduce cost for troop and crew chief/gunner seat procurement.

Integral-Armor Seats

Five integral-armor gunner's seat concepts have been presented. Of these concepts one is a fixed side-facing seat, two move longitudinally, and two swivel from a side-facing to a forward-facing position. All concepts utilize the same armored bucket configuration. Therefore, only the manner in which the bucket is supported and crash attenuated will be evaluated.

Concept F uses a suspension and stabilization system that is similar to most of the unarmored concepts. A very strong aircraft ceiling structure is required to support the armored bucket in this manner. Concepts G and H are similar in that they are floor mounted, slide vertically on a guide tube, have a universal joint at the base, and are stabilized longitudinally and laterally by torsion type energy attenuators. Concepts J and K rely on a stanchion tube between floor and ceiling for support and vertical stroke guidance. No lateral or forward crash attenuation is provided.

In selecting the best of these five armored seat concepts, a comparative analysis is made of their ratings for human factors, crashworthiness, reliability, maintainability, cost, simplicity, and weight. Human factors and crashworthiness have been weighted because of their prime importance.

The comparative results for the five armored seats show that Concept H received the highest score and Concepts J and F rated second. Concept K scored lowest due to its complexity, weight, and cost. Scoring of Concept G was also low because of tracking complexity and a lower crashworthiness value. Of the three highest rated concepts, F has a low crashworthiness score and has a high strength ceiling requirement. J is less attractive than H because it lacks a horizontal attenuation system. Concept H, a fixed floor-mounted swiveling 3-axis attenuated seat, was selected as the best integral-armor gunner's seat concept.

Modular-Armor Seats

Although only two modular-armor seat concepts are shown, all previously evaluated concepts are adaptable to the modular

armor principle. Whether the seat consists of tubing, fabric and webbing, or has a formed bucket, ceramic or other armor material can be added to these seats. The two unarmored concepts selected to illustrate the addition of armor panels have about the same evaluation rating in a modular-armor configuration as they had as unarmored seats.

Unarmored seats can be converted to modular-armor seats by adding armor plates to the tubular structure with angle clips (Figure 28). Weight increase for the basic seat structure to accept the crash loads from the addition of seat bottom and partial back armor would be negligible. Integral-armor seats can be converted to modular-armor seats by replacing the armor bucket with a formed or fabricated bucket to which armor plates can be added. The modular-armor seats, Concepts L and M, are adaptations of the unarmored seat concepts shown in Figures 17 and 22. Weight of the seat pan and back armor added to these ceiling-suspended seats is minimal; however, aircraft ceiling structural strength may be limited as to the amount of armor that can be added to the seat. Floor-mounted armor seats will have to be used in aircraft having ceilings which cannot support seats with armor. Selection of a modular-armor seat will depend upon aircraft structural capability. The selected unarmored seat and the selected armored seat can be adapted as the selected modular armored concepts.

CONFIGURATION

A configuration was selected, seat and restraint system mockup drawings were made, and the seat was evaluated prior to a Government evaluation.

Selection

The program statement of work required that an unarmored gunner's seat be selected, and a mockup be fabricated and installed in the Boeing YUH-61A UTTAS mockup. The principal considerations in the selection were adequate crashworthiness and gunner motion capability. Adequate crashworthiness is difficult to provide in a side-facing seat because side-facing seats are oriented in the least favorable direction for crashworthiness. Crash impact loads have predominantly forward and vertical components. Forward impact forces would place a high lateral acceleration on a gunner facing sideways, and human tolerance to lateral acceleration is low. It is preferable that the gunner have the capability of positioning his seat to face forward or aft when he does not have to face sideward to perform his function.

A review of the various unarmored seat concepts revealed that Concept C has the most advantages. Its swiveling capability provides good crashworthiness because it can be rotated from a side-facing to forward- or aft-facing position. Although higher in weight than the fixed side-facing seats, the crashworthiness advantages are considered worth the weight penalty.

The cantilever seat pan principle of Concept C provides a clear and unobstructed seating area which would not encumber gunner motions. One drawback to the concept is that a seat depth of 20 inches is required to cantilever an unobstructed seat pan of 15-inch depth. Total seat depth for the UTTAS installation is limited to 15 inches. Therefore, redesign of Concept C for UTTAS installation was necessary.

Seat Design

The Concept C design utilizes a cantilever seat pan suspension system. A tubular back frame acts as a compression member while tension straps in the plane of the auxiliary back suspend the seat pan at a point behind the seating area. Designing a seat which is limited to 15 inches in depth necessitated moving the tubular frame to the seat-pan back and the tension straps beside the seat pan in the seating area. This support point is 4.25 inches in front of the seat pan support point on Concept C, and although it appears that this will not encumber

gunner motion, it will have to be verified by mockup evaluation. The mockup seat, SK25067-10, is shown on drawings in Appendix B.

Restraint System Design

A restraint system is required which will permit the gunner to move out of the seat to maneuver the gun or to observe tail rotor clearance while landing in unprepared areas. The system should also restrain the gunner to the seat the instant he returns to the seat. Provisions should be made in the system to maintain the lap belt buckle in the proper relationship to the gunner, preventing the shoulder straps from pulling it up or the lap belt from pulling it sideways. Such a system was designed and is shown in Figure 31. It consists of a lap belt with retractors on each side of the seat and two shoulder straps connected in an inverted-Y arrangement to a single inertia reel strap. A waist strap, continuous with the lap belt, passes through adjusters at the lap belt buckle. A crotch strap is provided, one end of which is connected to the back of the waist strap. The strap passes under the crotch and an adjuster fitting on the other end plugs into the five-point lap belt buckle (Figure 31).

Human Factors Evaluation

Prior to the mockup demonstration with troops and gunners, a study of the seat was made to evaluate general human factors features. Seat rotation was the principal feature studied. If the seat was walked around, using the feet alone, the feet had to be picked up and put down several times for 90 degrees of rotation. A step in the floor, some brackets, and equipment stowed on the floor encumbered foot motion and further increased rotational time. Even with no floor encumbrances, walking the seat around was time consuming. Another method was to grasp nearby structure or the pilot's seat, raising the feet slightly off the floor, and rotate the seat by arm motion alone. This method reduced rotation time approximately 65 percent. A third method is to combine arm motion with an initial push with one foot. This was accomplished in approximately the same time as with the arms alone. The advantage of this method is that there is additional force available during the initial part of rotation. This may be needed to overcome spring-loaded detents if they are used to hold the seat in the side-facing position.

Rotation of the gun out of the way simultaneous with seat rotation was also studied. Although it is not necessary to move the gun for seat or occupant clearance during rotation, a flailing arm during impact could strike the gun if it is left in a sideward-pointing position.

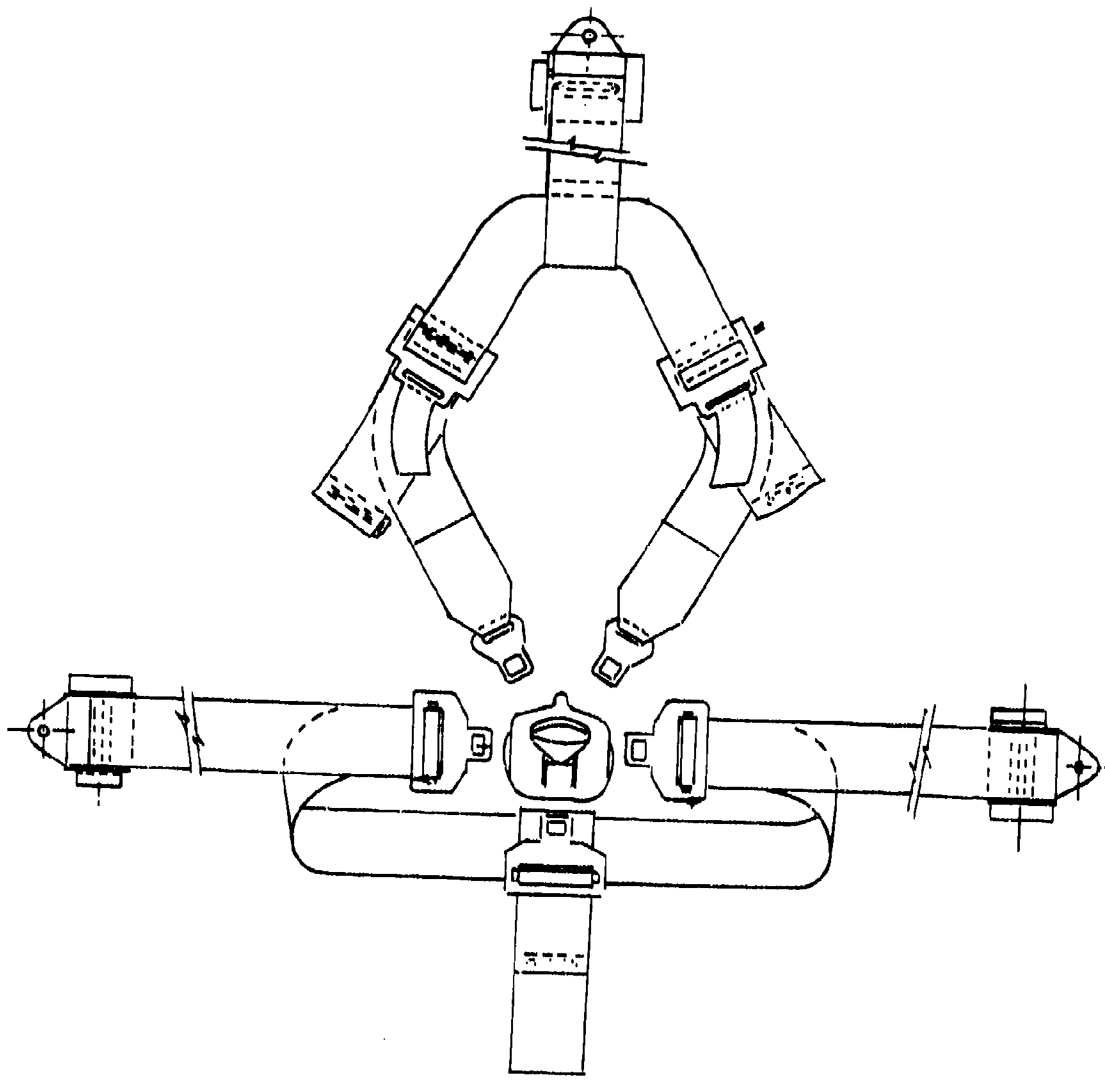


Figure 31. Waist Strap Restraint System.

An area of possible encumbrance for the gunner's feet is the swivel ring which is attached to the floor and extends 4 inches in front of the seat. This possibility will have to be evaluated by the gunners during the mockup demonstration.

When reviewing the seat drawings, some concern was shown regarding possible encumbrance to gunner operations by the seat-pan support strap. The strap, attached to the top of the tubular seat back at one end and to the seat pan at the other end, extends 4 inches from the seat back alongside the seating area. Examining the strap on the mockup seat and performing simulated gunnery motions did not show evidence of encumbrance. This will have to be verified by gunners during the mockup demonstration.

The seat was evaluated for adequacy of seating area, comfort and possible injury-producing areas. The seat was judged to provide adequate seating area, and it is comfortable. The headrest appears to be adequate for protecting the head if it were to strike the seat back. No other protuberances or injury-causing areas were noted. Proper adjustment of the auxiliary back flap was found to be required to prevent impingement of the spine against the rear seat-pan tube. This area might present a problem and requires further investigation.

FIRST MOCKUP DEMONSTRATION

A crashworthy gunner's seat developed for the Eustis Directorate and installed in the Boeing UTTAS mockup was evaluated in tests conducted at the Boeing Vertol Company. Government technical personnel, present to evaluate the tests, represented the following organizations:

- U.S. Army Air Mobility Research and Development Laboratory (USAAMRDL), Fort Eustis, Va.
- U.S. Army Human Engineering Laboratory (USAHEL), Aberdeen Proving Ground, Md.
- U.S. Army Aeromedical Research Laboratory (USARL), Fort Rucker, Ala.
- U.S. Army Combat Training and Development (USACTD), Fort Benning, Ga.
- Naval Air Development Center (NADC), Johnsville, Pa.

Troops and gunners were provided by USAHEL and were selected to approximate 5th, 50th, and 95th percentiles. The troops and gunners were used to evaluate the seat for gun motion

envelope capability, seat accommodations for various equipment, restraint system for fit, function, ingress and egress, and crashworthiness swivel provisions.

Gun Motion Envelope

The gun motion envelope evaluation involved seat placement relative to the gun, gun maneuvering from full-forward to full-aft firing and horizontal to full-down firing, restraint system extended length adequacy, and encumbrances with the seat. Gun motion studies were made with 5th, 50th, and 95th percentile gunners. The gun motion angles in excess of 70° forward, aft, and downward required for UTTAS were achieved by all gunners while attached to the seat with the retractable lap belt and shoulder harness restraint system. Lap belt and shoulder strap lengths stored on the inertia reels were adequate to perform the gun motion requirements and to lean out for observing tail rotor ground clearance. Maneuvering the gun through the full range of motions required standing up from the seat as planned (Figure 32). A 50th-percentile gunner with retractable restraint system attached is shown in Figure 33 in the three extreme-angle positions. Leg clearance for maneuvering in front of the seat was adequate, as was the clearance between gun butt and gunner's chest while seated. Seat installation geometry in the UTTAS is shown in Figure 34. Gunner window height and width, though minimal, was adequate to maneuver the gun through the required motion envelope.

The following problems were encountered while maneuvering the gun: 1) The seat swivel ring on the floor extends 4 inches in front of the seat and caused some encumbrance with the feet. 2) The seat was free to swivel, as no locks or detents were provided on the mockup seat. This caused the seat to turn back and forth as the gunner moved from the forward to aft firing positions.

Seat Design and Accommodations

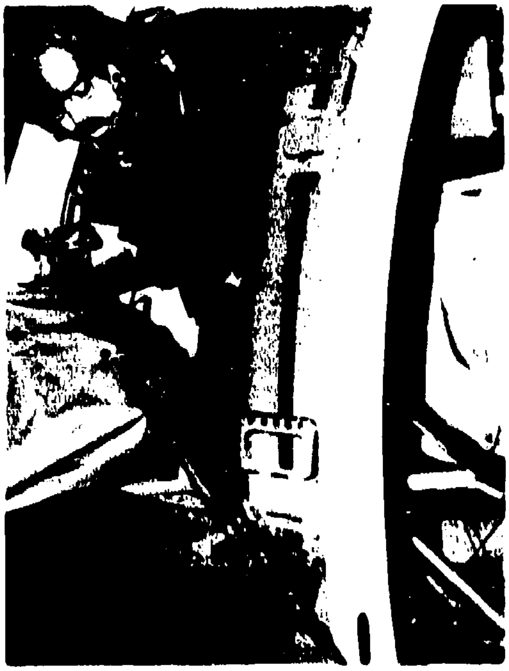
The seat is designed to accommodate gunners with survival vests or troops with full combat equipment and "butt" pack or medium rucksacks. The 15-inch-deep seat pan was adequate for gunner and troop comfort. Seat width of 22 inches was not excessive but could be reduced to 20 inches. Seat-pan suspension straps did not restrict or catch troop combat equipment or restrict gunner motions. The adjustable seat back accommodates a gunner with or without body armor and troops with or without combat packs and equipment. A back flap, when in place, provides a comfortable back support for the occupant who is not wearing a combat pack. Quick release of the back flap exposes a 7-inch-deep pocket which adequately accommodated "butt" pack or medium rucksack with combat assault loads. Figure 35 shows the auxiliary back flap in place for the gunner and removed

95th-Percentile Gunner With Survival Vest and Armor

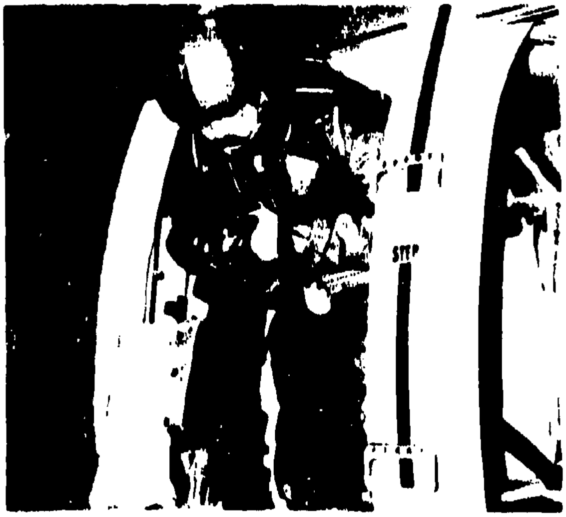
5-th Percentile Troop With Rucksack

Figure 32. Gun Motion Evaluation Using Troop and Gunner.

Firing Forward



Firing Aft



Firing Downward

Figure 33. Gun Motion Evaluation Using 50th-Percentile Gunner.

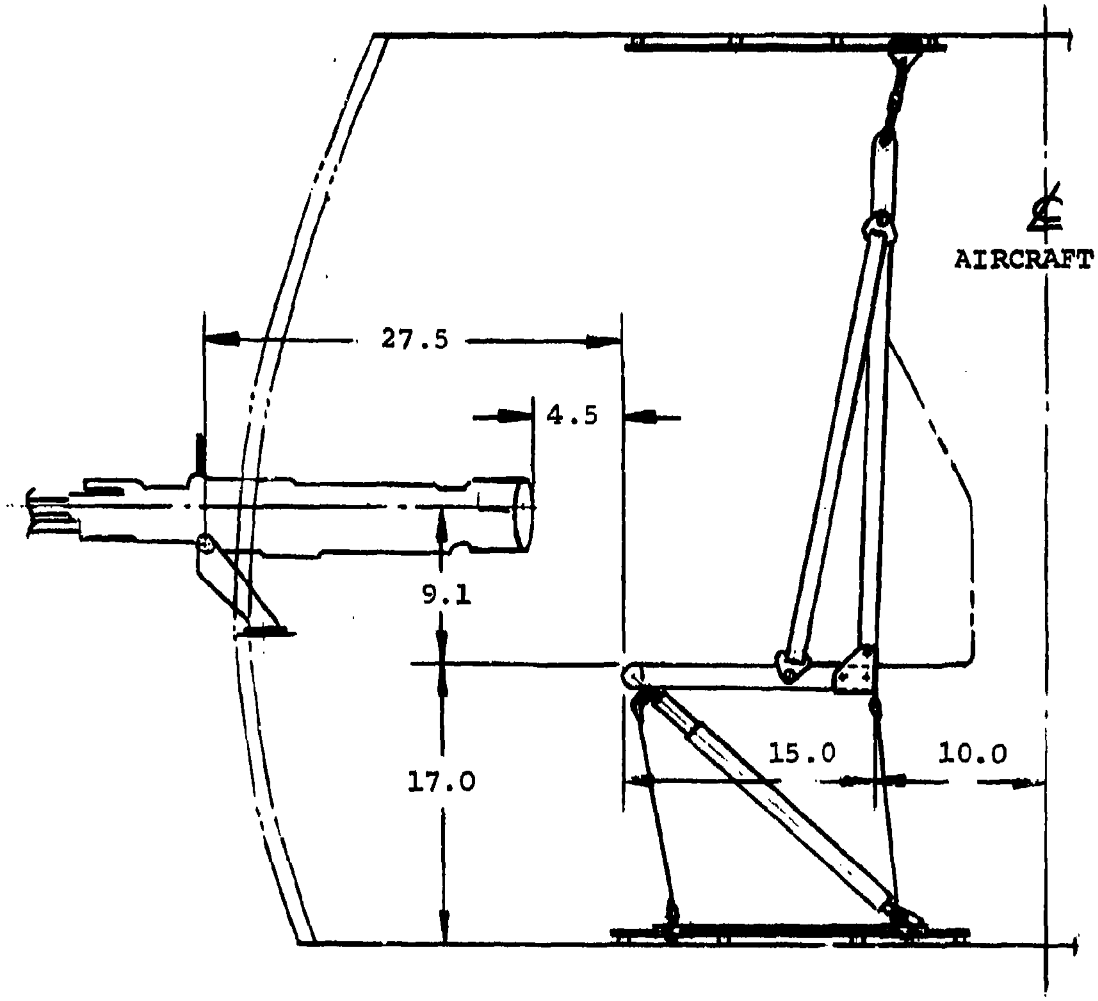


Figure 34. Seat Installation Geometry in Boeing UTTAS.

95th-Percentile Gunner
With Survival Vest

50th-Percentile Gunner
With Survival Vest

5th-Percentile Troop
With Medium Rucksack

Figure 35. Seating Adequacy Evaluation.

for the troop carrying a medium rucksack. In this figure the rucksack is barely visible due to the ample accommodation of the seat back pocket. Detail evaluation items were documented and are tabulated in Table 9.

The only design problem encountered with the seat was that under certain conditions the lower spine could impinge on the seat pan rear cross tube. This problem can be resolved by attaching the seat pan fabric to the rear tube the same way that the front and sides are attached rather than by the sleeve attachment used.

Restraint System

The waist strap restraint system described in Figure 31 was evaluated using various percentile gunners and troops (Figure 36). Times to ingress, hookup, unhook, and egress were recorded along with problems encountered. They are presented in Table 10 for the following conditions:

- With and without crotch strap using 5th-percentile gunners with warm weather clothing and no survival vest
- With crotch strap using 50th-percentile gunner with intermediate weather clothing and survival vest
- Without crotch strap using 95th-percentile gunner with intermediate weather clothing and survival vest
- Without crotch strap using 5th-percentile troop with intermediate weather clothing and medium rucksack without Lincloe frame
- Without crotch strap using 95th-percentile troop with intermediate weather clothing and medium rucksack without Lincloe frame.

The demonstration manifested a number of restraint system problems. Initial assistance was required by each new man in arranging and donning the restraint harness. Tangling of the waist strap and crotch strap was the principal factor causing the problem. These provisions are necessary to prevent the lap belt buckle from riding up and shifting during gun maneuvering.

Difficulty was experienced in reaching the shoulder straps, especially by larger gunners and troops wearing combat packs. Interference was experienced between the shoulder strap and pockets on the upper front of the survival vest (Figure 37). It is recommended that the survival vest pockets be moved outward approximately 2 inches.

TABLE 9. GUNNER'S SEAT EVALUATION, NO RESTRAINT

	Remarks
5th-Percentile Gunner With Survival Vest and Warm Weather Clothing	
a. Seat Depth	Ample
b. Seat Height for Leg Height	Adequate
c. Back Height, Angle, and Comfort	Adequate
d. Seat Pan Angle and Comfort	Adequate
e. Seat Width	Ample[1]
f. Seat Swivel Forward and Side Facing	Free Operation
g. Encumbrances With Seat During Gun Operation	Heels With Swivel Ring
95th-Percentile Gunner With Survival Vest and Intermediate Weather Clothing	
a. Seat Depth	Adequate
b. Back Height, Angle, and Comfort	Ample
c. Seat Pan Angle and Comfort	Adequate[2]
d. Seat Width	Ample
e. Seat Swivel Forward and Side Facing	Free Operation
f. Encumbrances With Seat During Gun Operation	Heels With Swivel Ring
95th-Percentile Troop With Rucksack and Intermediate Weather Clothing	
a. Pocket Adequacy for Assault Pack	Ample
b. Back Support for Troops With Flap Down	Adequate Support
c. Equipment Encumbrance During Ingress	No Problems
d. Equipment Encumbrance During Egress	No Problems
e. Equipment Snagging	No Problems
1. Could be reduced to 20 inches 2. Seat pan back tube can impinge on spine	

1. Single Reel Y-Type Shoulder Straps
2. Waist Strap
3. Lap Belt Extended

Figure 36. Waist Strap Restraint System.

TABLE 10. RESTRAINT SYSTEM EVALUATION	
	Remarks and Time
5th-Percentile Gunner With No Survival Vest, With Warm Weather Clothing and Restraint With Crotch Strap	
a. Donning and Hookup Problems	Many
b. Donning Time	37 Seconds
c. Shoulder Strap Height	Adequate
d. Shoulder Strap Length Allowing Full Gun Motion Envelope Operation	Adequate
e. Lap Belt Length Allowing Full Gun Motion Envelope Operation	Adequate
f. Restraint Straps Slip, Twist, or Come Off During Movements While Operating Gun	Lap Belt Twists and Jams on Reel
g. Release and Egress Evaluation (Buckle or Strap Hangup)	No Problem
50th-Percentile Gunner With Survival Vest, With Intermediate Weather Clothing and Restraint With Crotch Strap	
a. Donning and Hookup Problems	Many
b. Donning Time	31 Seconds
c. Shoulder Strap Height	Reach Problem
d. Shoulder Strap Length Allowing Full Gun Motion Envelope Operation	Adequate
e. Lap Belt Length Allowing Full Gun Motion Envelope Operation	Adequate but Unequal Adjustment
f. Strap Interference With Survival Vest Equipment	Top Pockets Interference
g. Restraint Straps Slip, Twist, or Come Off During Movements While Operating Gun	No Problems
h. Release and Egress Evaluation (Buckle or Strap Hangup)	Waist Strap Hung Up

TABLE 10 - Continued	
	Remarks and Time
5th-Percentile Gunner With No Survival Vest, With Warm Weather Clothing and No Crotch Strap Restraint	
a. Donning and Hookup Problems	Many
b. Donning Time	55 and 25 Seconds
c. Restraint Straps Slip, Twist, Ride Up or Come Off While Moving About and Operating Gun	No Problems
d. Release and Egress Evaluation (Buckle or Strap Hangup)	No Problems, Egress 2.5 Seconds
95th-Percentile Gunner With Survival Vest With Intermediate Weather Clothing and No Crotch Strap Restraint	
a. Donning and Hookup Problems	Many
b. Donning Time	63 and 50 Seconds
c. Restraint Straps Slip, Twist, Ride Up or Come Off While Moving About and Operating Gun	No Problems
d. Release and Egress Evaluation (Buckle or Strap Hangup)	No Problems, Egress 2 and 4 Seconds
5th-Percentile Troop With Rucksack, With Intermediate Weather Clothing and No Crotch Strap Restraint	
a. Donning and Hookup Problems	Many
b. Donning Time	52 and 32 Seconds
c. Encumbrance With Combat Equipment	No Encumbrance
d. Release and Egress Evaluation (Buckle or Strap Hangup)	Hung Up on Canteen and Ammunition Pouch, Egress 11 and 26 Seconds

Figure 37. Shoulder Strap Interference With Survival Vest Equipment.

The gunner's restraint system was evaluated with and without the crotch strap, and it was determined after several tests that the back band prevented the buckle from riding up while maneuvering the gun. For this reason the crotch strap was not used on subsequent tests. The lap belt tended to twist and jam on the reels when being retracted during gun maneuvering.

Egress from the restraint system was performed by the gunners without hangup on the survival vest. Had the gunners been wearing sidearms, as they sometimes do, a hangup would be possible. Troop egress from the restraint system produced a hangup on every test. The loop formed by the back strap and lap belt caught on the canteen, trenching tool, and ammunition pouch. The conclusion reached was that the restraint system was unsatisfactory for troops or gunners use due to its complexity, excessive time required for donning, and snagging on combat equipment.

A modification of the system was recommended which eliminates all the negative features. The crotch strap attachment was moved from the back band to one side of the lap belt, and the back band and lap belt buckle adjusters were removed. The resulting system is a conventional lap-belt/shoulder-strap system with the exception that a thigh strap is added to prevent the buckle from riding up. The mockup system was revised to simulate the proposed system by sliding the crotch strap attachment from the back strap to the lap belt and by tieing the back strap at the lap belt buckle. This system was evaluated and found to function satisfactorily while maneuvering the gun. Ingress and egress times could not be checked because of the inoperability of the system. The revised system was evaluated during the second mockup demonstration.

Crashworthiness Swivel Provision

The seat was evaluated for its capability of rotating from a side-facing to a forward-facing position. Approximately one second or less was required for the transition from a side-facing gunnery operation position. This time included rotating the gun out of the way (Figure 38).

All of the evaluators who sat in the gunner's seat and swiveled it from the side- to forward-facing position, and all those who observed the operation, agreed to the ease of the operation. They also agreed that the ability to orient the seat in a longitudinal direction would improve crashworthiness since the human tolerance is low for occupants in side-facing seats during predominantly longitudinal impacts. The consensus was that the requirement for side-facing gunner seats to swivel for improved crashworthiness should be included in the gunner's seat military specification. There was disagreement, however, on whether the seat should swivel forward or rearward. The

Seat Facing Sideward

Seat Facing Forward

Gunner Swiveled for Crash Impact

Figure 38. Seat Swivel Capability for Improved Crashworthiness.

advantages and disadvantages of rotating the seat to a forward-facing position are as follows:

- Occupants prefer to ride facing forward.
- There is no uneven load distribution on occupant's back caused by the irregular shape and size of combat packs.
- Human tolerance to impact in the forward direction is high, and the restraint system is adequate for high forward accelerations.
- Forward impacts tend to rotate the seat to a forward-facing position.
- The seat back protects the gunner from loose weapons and equipment carried by forward-facing troops.
- There is a chance of the occupant striking objects if they are within the rotational envelope.
- The egress route is longer if the doorway is to rear of the gun opening.
- There is a chance of submarining (same as forward-facing troops).

The advantages and disadvantages of rotating the seat to an aft-facing position are as follows:

- The restraint is less critical (no submarining).
- Egress is easier if the doorway is to the rear of the gun opening.
- Distribution of the load on the occupant's back is poor when he is wearing combat pack which is of irregular size and shape.
- There is less tendency for the seat to automatically rotate to a rear-facing position during forward impacts.
- Occupants do not desire to ride facing rearward.
- The probability of injury from loose weapons and equipment carried by forward-facing troops is greater.

A review of these considerations indicated that rotation of the seat from a side-facing to a forward-facing position

appeared to be preferable. The seat should be rotated forward during takeoff and landing, during noncombat flights, and when the occupant has warning of impending crash. A 360° rotational capability could be considered.

Recommendations From First Mockup Demonstration

After the mockup evaluation, the Government recommended changes to the seat. These changes were incorporated in the mockup seat for evaluation at the second mockup demonstration. The following changes were recommended:

- The back strap should be eliminated from the restraint system, and the crotch strap should be fastened around the thigh and attached to the lap belt.

- The buckle for the restraint system should be attached to the thigh strap and not the lap belt; this will prevent the buckle from riding up during maneuvering by the gunner.

- The buckle should be changed from a rotating lever type to a lift lever type.

- Guides and/or stiffeners should be added to the shoulder straps to aid the fully equipped gunner in reaching the straps.

- The seat width should be reduced from 22 inches to 20 inches; this will reduce the weight of the seat and also provide a little more room for egress.

- Everyone was pleased with the ability of the seat to swivel side to forward facing, side to aft facing, 180°, or 360°. It was agreed that the seat should definitely have the ability to swivel side to forward facing, and there was no objection to the seat swiveling aft so long as the forward-facing capability was kept. A 360° rotational capability should be incorporated.

- The center of the bottom circle on which the seat swivels should be moved back 2 inches to allow for automatic positioning of the occupant in a forward direction during crash.

- There should be some detent feature in the swiveling mechanism to allow for some type of positioning for the seat in each direction it faces.

- Guides and/or stiffeners should be added to the lap belt retractors.

Conclusions From First Mockup Evaluation

The consensus of the evaluators was most favorable regarding the rotational capability of the seat, its ease of rotation, comfort, and the ample accommodation for troop combat equipment in the back pocket. No equipment snagging, encumbrance with seat-pan suspension straps, or any other functional problems were encountered during the evaluation. Some encumbrance was experienced with the rotational ring at the front of the seat and with the seat-pan tube at the back of the seat. These encumbrances were easily remedied for the second mockup evaluation.

The restraint system exhibited many problems. Excessive time in donning the restraint system was caused by its complexity. Difficulty in reaching shoulder straps and jamming of lap belt retractors contributed to the excessive time. Snagging of troop equipment made the restraint system in this configuration unacceptable. A new restraint concept was recommended for evaluation at the second mockup demonstration.

SECOND MOCKUP DEMONSTRATION

A second evaluation was conducted on the gunner's seat mockup after it was modified as recommended at the first evaluation. The seat was installed in the Boeing UTTAS aircraft mockup. Government personnel present to evaluate the seat represented the U.S. Army Human Engineering Laboratory (USAHEL), Aberdeen, Maryland, and the U.S. Army Air Mobility Research and Development Laboratory (USAAMRDL), Fort Eustis, Virginia.

Modifications

The following modifications were made to the seat for the second demonstration:

- The shoulder harness was modified from a single-reel inverted-Y strap arrangement to double-reel independent-strap arrangement, and guides extended the straps 6 inches from the back face of the seat (Figure 39).
- The lap belt was modified by removing the waist band and moving the crotch strap attachment from the waist band to the lap belt segment (Figure 40).
- The seat width was reduced from 22 to 20 inches (Figure 41).
- Attachment of the seat-pan fabric to the back tube was revised to minimize the probability of spine contact with the seat-pan frame (Figure 42).

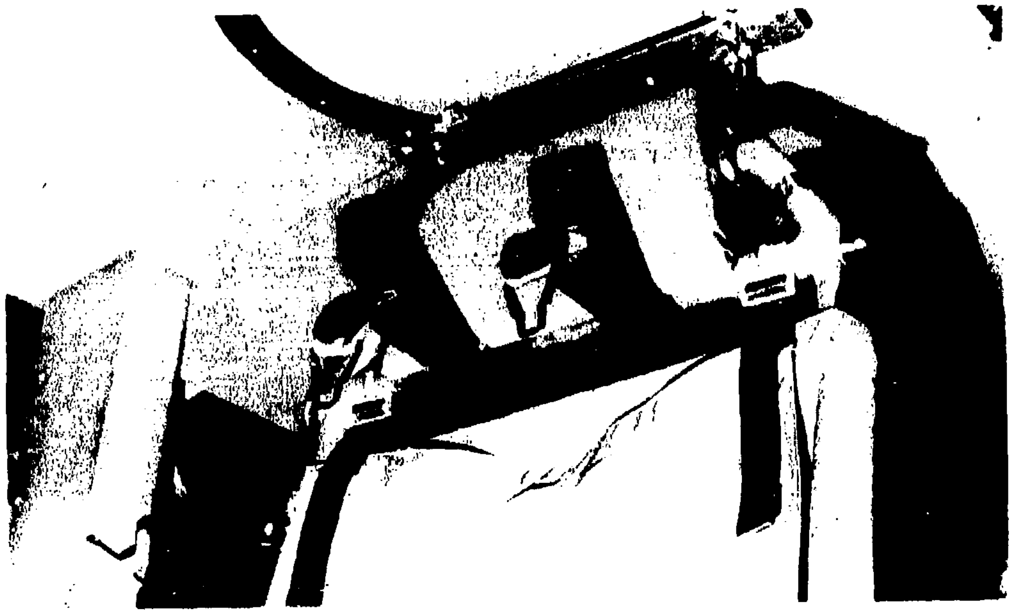


Figure 39. Shoulder Strap Guides.

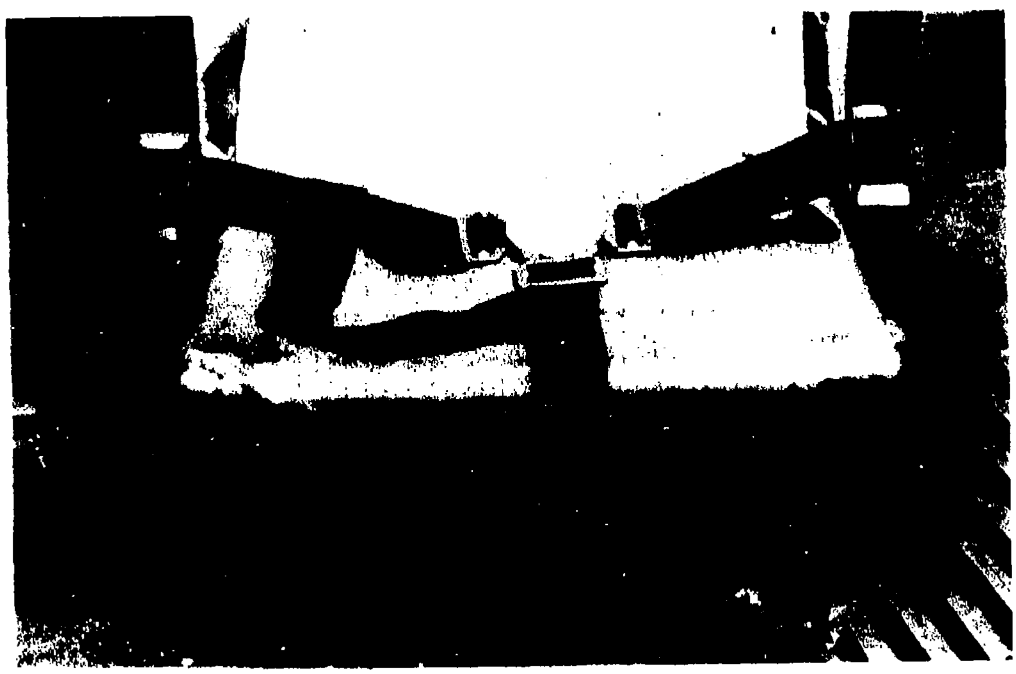


Figure 40. Thigh Strap and Lap Belt Arrangement.

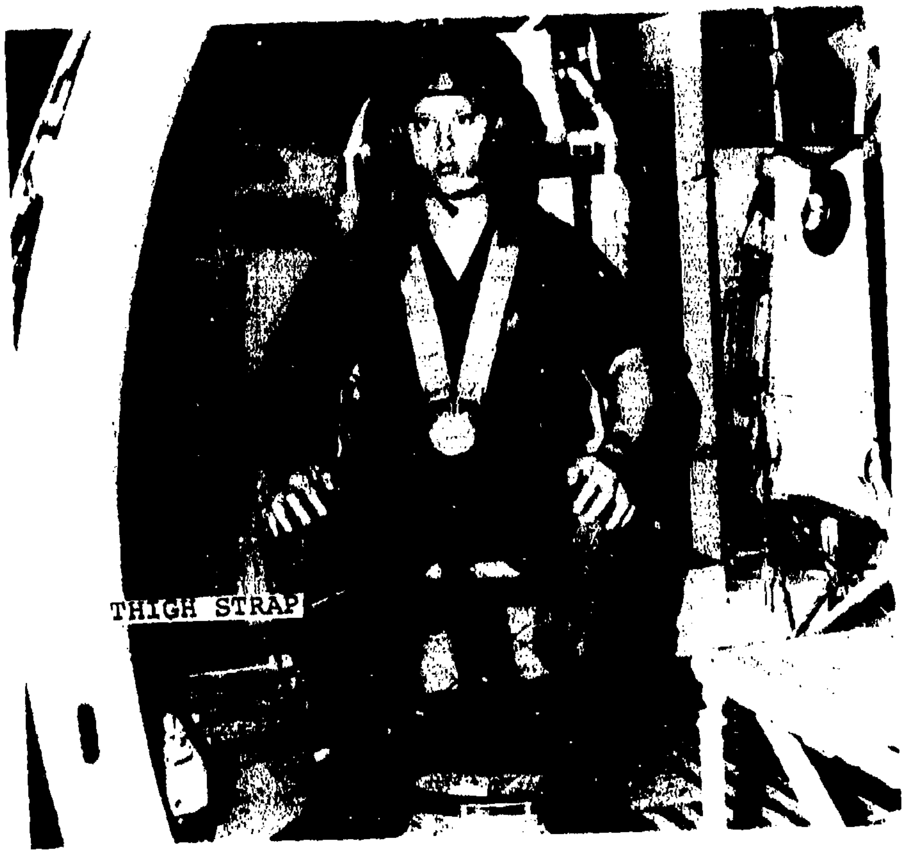


Figure 41. Thigh Strap Restraint System With 20-Inch Seat.

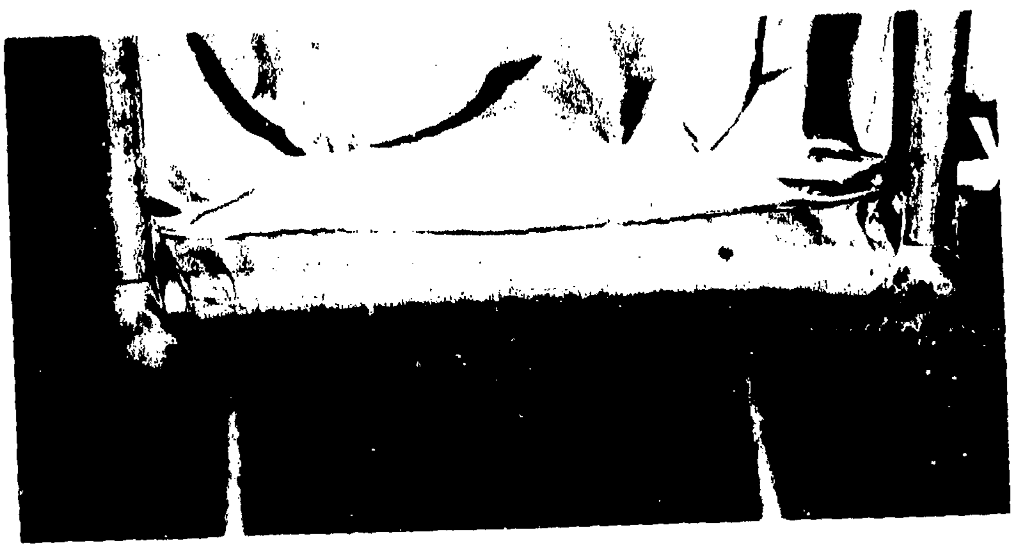


Figure 42. Modified Seat-Pan Fabric Attachment.

- The rotational capability of the seat was increased from 90° to 360° by using full-circle rings at ceiling and floor (Figure 43).

- The front of the swivel ring at the floor was moved back 4 inches so as not to extend beyond front of the seat.

- The swivel rings at floor and ceiling were decreased in diameter, and the center of rotation of the seat was moved back 2 inches (Figure 43).

- Strap guides were added to the lap belt reels (Figure 44).

- A detent was added to hold the seat in the side-facing position until rotated forward or aft (Figure 45).

Restraint System Evaluation

The modified restraint system was evaluated using 5th- and 95th-percentile gunners with and without survival vests. The new features being evaluated were the independent shoulder straps, with strap guides at the top of the seat back, and the thigh strap connected from the lap belt segment around the thigh and to the lap belt buckle (Figures 39 and 40). The shoulder strap guides aided the gunner in reaching the straps. Each new man required instruction in use of the thigh strap, since it is an unconventional feature.

Hookup time for the new restraint system was 50 to 75 percent less than the time required for the restraint system used in the first evaluation. Detail times are tabulated in Table 11. Time reduction was due to the easy access to shoulder straps and the simplified lap belt. Twisting of the lap belt on the reels, experienced in the first evaluation, was prevented by the added strap guides (Figure 44).

The principal problems encountered with the restraint system were inadequate length of the shoulder straps and the straps slipping off the gunner's shoulders while he maneuvered the gun. Standard size shoulder harness reels are not large enough to store sufficient strap to permit full retraction to the top of the seat back and at the same time permit the gunner to move away from the seat to fully maneuver the gun or to lean out to observe tail rotor clearance. A larger reel to store approximately 18 additional inches of strap (58 inches in all) is required. An 18-inch segment was added to the mockup shoulder straps to permit gun maneuvering as shown in Figure 46. The thigh strap, shown around the thigh in Figure 46, prevented displacement of the lap belt buckle during gun maneuvering. Straps slipping off the gunner's shoulders

Figure 43. Full-Circle Seat Rotation.

Figure 44. Lap Belt Reel Strap Guide.

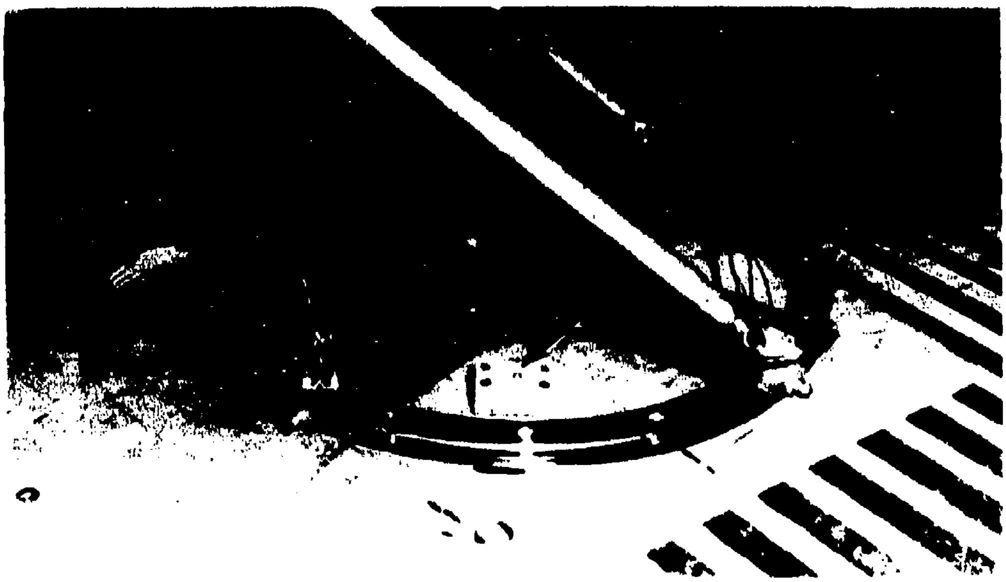


Figure 45. Seat Swivel Detent.

TABLE 11. RESTRAINT SYSTEM EVALUATION	
Restraint With Thigh Strap and Double Shoulder Strap	Remarks and Time
1. 5th-Percentile Gunner Without Survival Vest, With Warm Weather Clothing	
a. Hookup Problems	None
b. Donning Time	20.0 and 17.5 Sec
c. Shoulder Strap Height Adequacy	Ok
d. Shoulder Strap Length Adequacy Allowing Full Gun Motion Envelope Operation	18 in. Too Short
e. Adequate Lap Belt Length Allowing Full Gun Motion Envelope Operation	Ok
f. Restraint Straps Slip, Twist, or Come Off During Movements While Operating Gun	Shoulder Straps Slipped Off
g. Release and Egress Evaluation (Buckle or Strap Hangup)	Ok 1.5 and 1.0 Sec
2. 95th-Percentile Gunner Without Survival Vest, With Warm Weather Clothing	
a. Hookup Problems	Thigh Strap Under Corner of Seat
b. Donning Time	17.0 and 15.0 Sec
c. Release and Egress Evaluation (Buckle or Strap Hangup)	Thigh Strap Not Ejected 1.5 and 1.0 Sec
3. 95th-Percentile Gunner With Survival Vest and Warm Weather Clothing	
a. Hookup Problems	Shoulder Strap Guide Through Helmet Wire
b. Donning Time	17.0 and 24.0 Sec
c. Shoulder Strap Height Adequacy	Ok
d. Shoulder Strap Length Adequacy Allowing Full Gun Motion Envelope Operation	18 in. Too Short
e. Adequate Lap Belt Length Allowing Full Gun Motion Envelope Operation	Ok
f. Strap Interference With Survival Vest Equipment	Shoulder Straps and Vest Pockets
g. Restraint Straps Slip, Twist, or Come Off During Movements While Operating Gun	Shoulder Straps Slipped Off
h. Release and Egress Evaluation (Buckle or Strap Hangup)	1.5 and 1.5 Sec

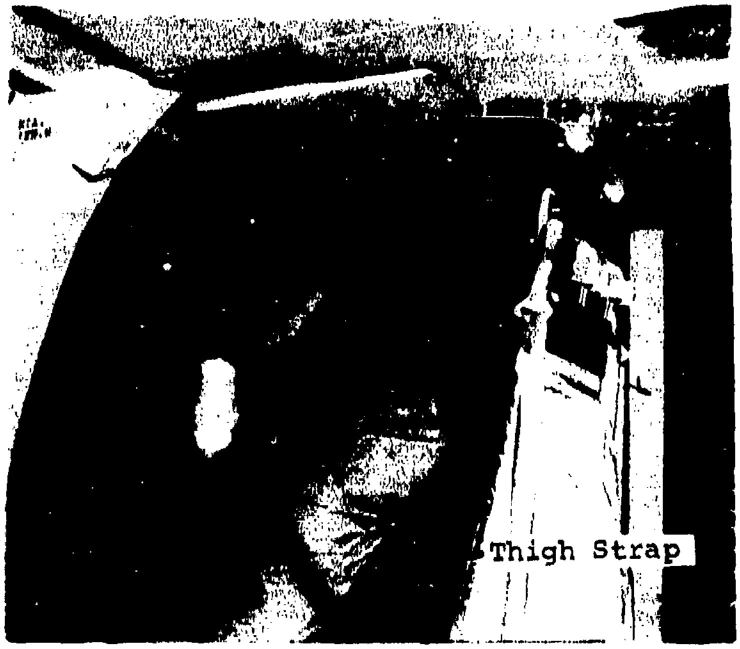


Figure 46. Restraint System Extension During Gunnery Motions.

during gun maneuvering were the most serious problem. Use of independent straps, necessary to permit full retraction to the guide at top of the seat back, prevents joining the straps together behind the gunner's neck. Straps joined in an inverted-Y arrangement appear to be necessary to prevent slipping. Fully retracted straps cannot be used with the Y arrangement, and an increase in time is required to find and connect the shoulder straps.

The following additional problems were encountered with the restraint system:

- On one occasion the thigh strap fitting was plugged into the lap belt socket on the buckle.
- On one occasion the thigh strap was hooked up while looped under the corner of the seat.
- On one occasion the shoulder strap guide extended through the microphone wire loop on the gunner's helmet, and the shoulder strap was pulled down and connected while through the wire loop.

Seat Evaluation

The modified crashworthy gunner seat mockup was evaluated for size, encumbrance during gunnery maneuvers, accommodation, comfort, ingress and egress, and seat swivel. Seat evaluations were conducted under the following conditions:

- With 5th-percentile gunner wearing warm weather clothing helmet and no survival vest
- With 95th-percentile gunner wearing warm weather clothing, survival vest, and helmet

Details of items evaluated are shown in Table 12 with remarks and seat swivel times. Seat height and depth were suitable for 5th- and 95th-percentile gunners. The reduced seat width (20 inches) was not excessive for the 5th-percentile gunner without survival vest (Figure 47) and was adequate for the 95th-percentile gunner with survival vest (Figure 48). Encumbrance with the seat pan support straps due to decreased seat width was not experienced during gun maneuvering.

The seat is designed to accommodate a gunner with a survival vest or a troop with butt pack or medium rucksack. For use by troop wearing packs, the auxiliary back flap is unhooked and folded to expose the back pocket which accommodates the pack (Figure 49). The back flap remains in place for gunner operation and was evaluated to be comfortable with or without wearing a survival vest (Figures 47 and 48). Comfort was

TABLE 12. GUNNER'S SEAT EVALUATION	
	Remarks and Time
5th-Percentile Gunner Without Survival Vest With Warm Weather Clothing	
a. Seat Depth Adequacy	Ok
b. Leg-Height to Seat-Height Adequacy	Ok
c. Back and Head Rest Height, Angle, and Comfort	Ok
d. Seat Pan Angle and Comfort	Ok
e. Seat Width Adequacy	Ok
f. Encumbrances With Seat During Gun Operation	None
g. Stow Gun and Swivel Seat Forward	1.0 and 1.0 Sec
h. Stow Gun, Swivel Seat Aft, and Egress	2.5 and 2.0 Sec
95th-Percentile Gunner With Survival Vest and Warm Weather Clothing	
a. Seat Depth Adequacy	Ok
b. Back and Head Rest Height, Angle, and Comfort	Ok
c. Seat Pan Angle and Comfort	Ok
d. Seat Width Adequacy	Ok
e. Encumbrances with Seat During Gun Operation	None
f. Stow Gun and Swivel Seat Forward	1.7 and 2.0 Sec
g. Stow Gun, Swivel Seat Aft, and Egress	3.0 and 3.5 Sec

Figure 47. 5th-Percentile Gunner Without Survival Vest.

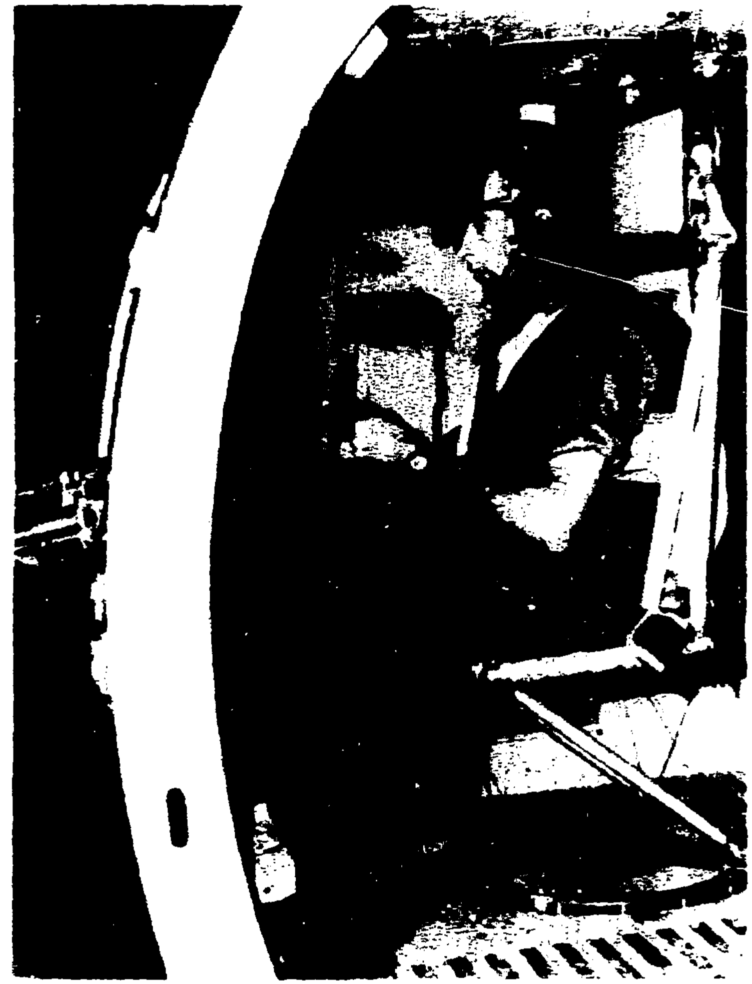


Figure 48. 95th-Percentile Gunner With Survival Vest.

Figure 49. Back Flap Folded for Combat Pack Accommodation.

improved by the modified attachment of the seat pan fabric to the back tube (Figure 42).

The modified seat is capable of swiveling from a side-facing position to a forward- or aft-facing position, and will also swivel 360°. The swivel feature provides improved crashworthiness by allowing the gunner to face in the predominant impact direction. The seat was evaluated for rotation using a 5th-percentile gunner without survival vest and a 95th-percentile gunner with survival vest. Rotational times were evaluated starting with the gunner standing and firing the gun. The 5th-percentile gunner required only one second to sit down, swing the gun to the side, and swivel the seat to a forward-facing position. A slightly longer time was required by the 95th-percentile gunner due to his size and the weight and bulk of the survival vest. Aft rotation was evaluated along with egress, starting from a standing gun-firing position. The minimum time required to sit down, rotate the gun, swivel the seat aft, release the restraint system, and egress from the aircraft was 2 seconds for the 5th-percentile gunner and 3 seconds for the 95th-percentile gunner (Table 11). No encumbrance was experienced between feet and floor swivel ring which had been moved back 4 inches. Moving the center of seat rotation back 2 inches improved ease of seat rotation and increased the probability of automatic seat rotation by crash impact loads. The mockup detent which prevents seat rotation during gunnery operations failed due to spring malfunction. However, it functioned for a sufficient length of time to demonstrate that it will satisfactorily prevent seat rotation during gunnery operations, but will release when force is applied to the seat to swivel forward or aft.

Conclusions From Second Mockup Evaluation

The double-reel shoulder strap system is not satisfactory and should be replaced with the inverted-Y shoulder strap system used in the first mockup evaluation. The Y arrangement prevents the straps from slipping off the gunner's shoulders and permits use of a standard size reel. The 20-inch seat was adequate in width for a 95th-percentile gunner. No contact between the back of the seat-pan frame and the spine occurred as a result of the seat-pan modification. Seat rotation from side-facing to forward- or aft-facing positions and 360° rotation functioned well and should be made a requirement for side-facing gunner's seats to improve occupant tolerance to forward crash impact loads.

CH-47 GUNNER'S SEAT DESIGN DEVELOPMENT

The contract requirements were to perform a design development of an unarmored crashworthy gunner's seat system, in accordance with the Crashworthy Gunner Seat draft military specification, for the U.S. Army CH-47 helicopter. The development included a seat design, stress analysis, occupant crash hazards analysis, human factors evaluation, and operational suitability analysis.

SEAT DESIGN CONSIDERATIONS

Before a seat can be designed, the gun installation, aircraft structure, and available points of attachment in the aircraft must be considered. The gun in the CH-47 is mounted in a high window opening and is suitable for standup gunnery operation. A high seat must be designed to be compatible with the gun installation; otherwise, extensive aircraft modification would be required. A rollup door is located at the right-hand gunner's station. Installation of a ceiling-mounted seat, which is the preferred type, must not interfere with door operation. Structural beams are not available in the aircraft floor under the area where the seat could be directly attached. Extensive aircraft rework would be necessary to add structure under the floor. Adding structure on top of the floor to beam the seat loads over to existing structure would not require aircraft rework and may be acceptable as long as the structure is quickly removable.

SEAT CONCEPT SELECTION

In selecting an unarmored gunner's seat concept for the CH-47 aircraft, the swivel seat concept selected as the best of the six concepts evaluated was reviewed. It was determined that it would not be feasible to install the swivel ring at the ceiling of the CH-47 because the side entrance door rolls up through the area above the seat. Also, installation of the floor swivel ring would require the addition of backup structure under the floor.

The seat concept which received the second highest score was investigated and was selected for adaptation to the CH-47 aircraft. This concept is similar to the concept selected in the USAAMRDL Troop Seat Investigation Program as the best of 19 concepts evaluated. The concept was modified by increasing the 17-inch seat height to 22 inches. Floor attachments were made to a beam added to the top of the floor which picks up existing floor tiedown fittings. The seat structural members were sized to withstand the increased lateral loading of

longitudinal impact. Detail drawings of the CH-47 gunner's seat are shown in Appendix B.

CH-47 AIRCRAFT MODIFICATIONS

The contract statement of work specified that modifications to the CH-47 aircraft shall be minimal. This criterion was adhered to in the design of the CH-47 seat installation. The following modifications are required; the drawings which show the modifications are included in Appendix B.

- Add two eyebolts to station 120 floor support angle (SK26143).
- Add a trunnion fitting to the station 120 frame at the ceiling (SK26143).
- Add a trunnion fitting to the station 160 frame at the ceiling (SK26143).
- Provide a truss to span from station 120 to station 160 from which to suspend the seat (SK26143).
- Provide a beam above the floor to span between existing cargo rails and attach to existing quick disconnect studs (SK26143).
- The top step of the foldup entrance ladder may have to be hinged to eliminate encumbrance during gunnery operations (see Figure 2).

These modifications are for the right-hand seat installation. Modifications for the left-hand seat would be the same except that there is no entrance ladder on the left side.

STRESS ANALYSIS

A load and stress analysis was performed for the CH-47 gunner's seat and the necessary structure and fittings for adapting the seat to the aircraft. Existing aircraft structure was investigated to determine if it would withstand the crash loads which would be imposed by the seat. All aircraft structure to which the seat adapters were attached and the carry-through structure was found to have ample margins of safety without requiring reinforcement.

CRASH HAZARDS ANALYSIS

An analysis to determine the statistical probability of spinal injury was performed and was discussed previously in this report. A wire-bending energy attenuator producing a force-deflection curve is recommended to absorb vertical impact forces (see Figure 16). A sustained force level of 3,250 pounds divided between the two vertical attenuators is required to limit the 95th-percentile impact acceleration on a 50th-percentile gunner to 14.5g. This force level will maintain the Dynamic Response Index to within the 5-percent probability limit for spinal injury of the 5th- through the 95th-percentile gunners. Seat stroke for a 42-fps impact velocity will be 13.5 inches for the 50th-percentile gunner, assuming that no energy is absorbed by the CH-47 landing gear. The 19-inch stroking capability of the seat is ample to cover the stroking requirements for a 95th-percentile gunner.

The seat provides tubular energy attenuators for longitudinal crash impacts. Clearance between the forward side of the seat and the radio rack (see Figure 1) on the left side of the aircraft is approximately 10 inches, which is within the minimum stroking range specified in the Crashworthy Gunner Seat draft military specification. The seat is capable of several more inches of stroke; this can be taken advantage of at the right gunner station because of the soft panel at station 120 which can be penetrated (see Figure 2).

Annealed stainless steel cables are provided on the seat for energy attenuation during lateral crash impacts. Clearance with the side of the aircraft and between seat backs is ample to permit seat stroking above the minimum recommended in the Crashworthy Gunner Seat draft military specification.

HUMAN FACTORS EVALUATION

A human factors evaluation of the CH-47 gunner's seat was made by reviewing the features of the crashworthy troop seat (Figure 50) developed under Eustis Directorate contract DAAJ02-72-C-0077 and the swiveling gunner's seat mockup discussed previously in this report. The CH-47 gunner's seat uses many features of these seats. The restraint system developed for the swiveling gunner's seat was evaluated and was found to be suitable for the CH-47 gunner's seat. This restraint system permits the gunner to maneuver the gun through its full motion envelope and automatically retracts to fully restrain the gunner for crash impacts as soon as he is seated. The restraint system does not encumber the gunner and does not slip during gunnery operations.

The seat was evaluated for adequacy of seating area, comfort,

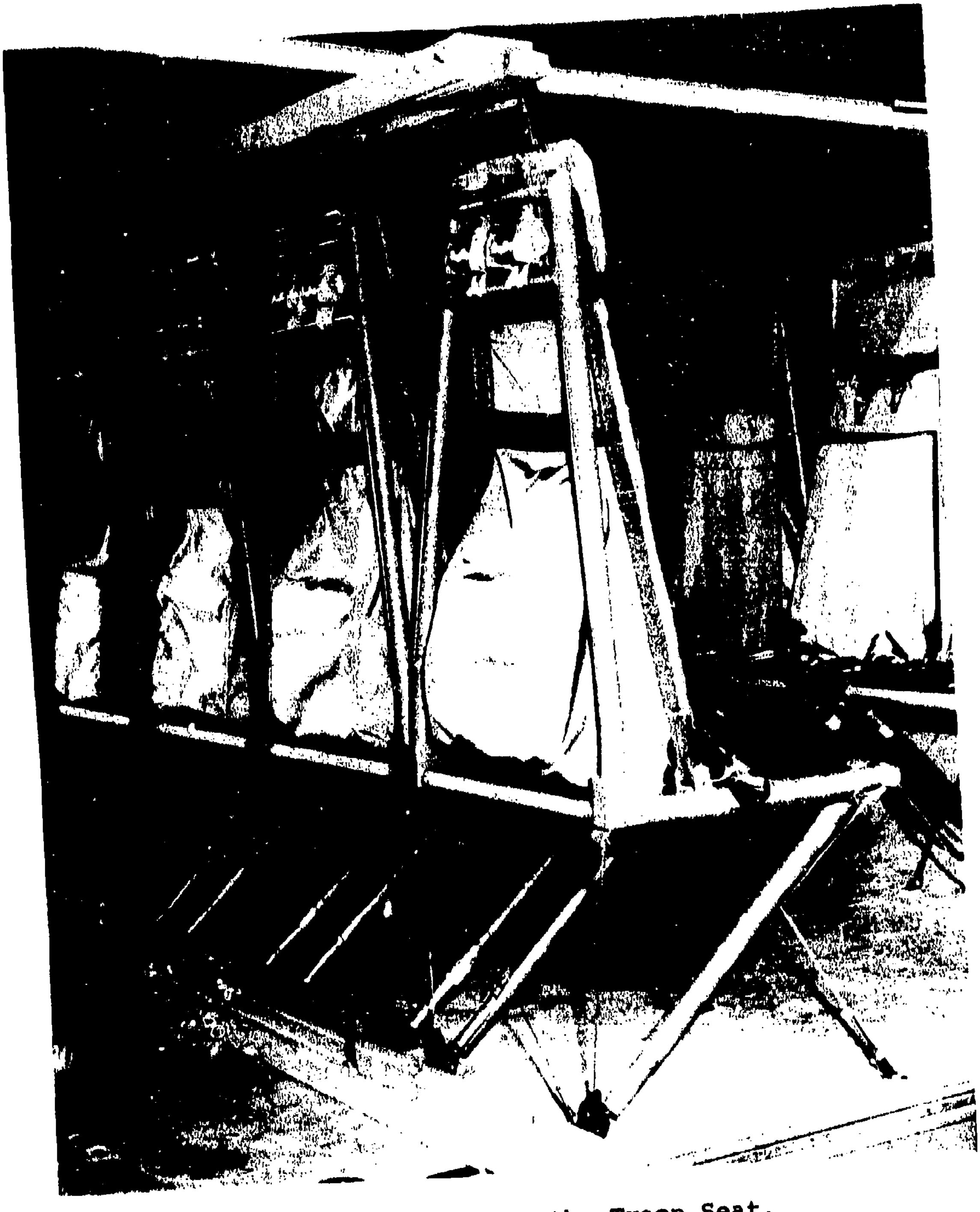


Figure 50. Crashworthy Troop Seat.

accommodations, encumbrances, gunner motions and possible injury-producing areas. The 15- by 20-inch seating area is adequate, and a similar seat was found to be comfortable. Adequate provisions are made behind the removable seat back flap to accommodate a troop's combat pack. A slight encumbrance may be experienced during seat ingress and egress due to the diagonal floor attachment cable on the aft side of the seat. The cables are canted aft to connect to the existing floor attachments in the CH-47 aircraft. Removal of the encumbrance would require the addition of structure under the aircraft floor. The degree of encumbrance, if any, will have to be determined by mockup. Sideward gunner motions during gun operation would be unencumbered because the seat pan is cantilevered and does not require supports above or to the sides of the seating area. The head rest appears to be adequate for protecting the head if it were to strike the seat back. No other protuberances or injury-causing areas were noted.

OPERATIONAL SUITABILITY ANALYSIS

Operational suitability considers weight, cost, removal time, environmental conditions, maintainability, and reliability.

Weight

The side-facing gunner's seat designed for installation in the CH-47 aircraft is estimated to weigh 12.4 pounds. Restraint harness and four inertia reels add an additional 3.5 pounds for a total seat system weight of 15.9 pounds. Bottom and partial back armor would add 16 pounds to the seat weight. Weight of structural provisions for installing the seat in the CH-47 aircraft is not included in seat weight; it is an additional 3 pounds.

Cost

Cost of the CH-47 gunner's seat in production quantities has been estimated by a seat fabricator as being approximately 25 percent higher than the standard one-man, free-standing, noncrashworthy seat currently in use in the UH-1 aircraft. This is a small price to pay considering the improved protection afforded by a crashworthy seat. Comparing the two types of seats, the noncrashworthy seat is designed to withstand 8g in the forward, vertical, and lateral directions, while the crashworthy seat will withstand crash impact loads of 24g, 48g, and 18g in the forward, vertical, and lateral directions, respectively. The crashworthy seat also provides shoulder restraint in addition to the lap belt provided for both seats.

The need for crashworthy gunner seats is shown in the noncombat fatality figures for survivable Army aircraft accidents from

July 1964 through June 1969. The figures show that 51.2 percent of the fatalities were troops/passengers and 21.3 percent were crew chief/gunners, as compared to 27.5 percent for pilots/copilots.

Removal Time

Seat removal requires the release of four quick disconnects fitting at the floor and two pin disconnects at the ceiling. Seat tension must be relaxed before the disconnects can be released. Two overcenter toggle latches are provided for seat tensioning. It is estimated that release of the two toggle latches, four floor connections, and two ceiling connections can be accomplished in 30 seconds or less.

Environmental Evaluation

An evaluation was made of the ability of the gunner's seat design to comply with the environmental requirements of the proposed gunner's seat military specification as detailed in the environmental test methods of MIL-STD-810. The following environmental factors were evaluated.

Temperature--The seat system was reviewed to determine whether materials and construction would withstand nonoperating exposure as well as deliver specified performance when subjected to the high and low temperatures specified in Environmental Test Method 501, Procedures I and II, and Method 502 of MIL-STD-810. The following conditions can be experienced at high temperatures according to the test procedures:

- Permanent set of packings and gaskets
- Binding of parts in complex constructions due to differential expansion of dissimilar metals
- Discoloration, cracking, bulging, checking, or crazing of rubber, plastic, or plywood parts
- Partial melting and adhering of sealing strips

None of these materials or conditions are present in the gunner's seat design. The materials and construction used are not expected to be affected by the high temperatures. Of the materials used, polyester fabric and webbing are the materials most sensitive to heat; however, they withstand heat in excess of the test temperatures during the dying process without being affected.

Conditions which could be experienced at low temperatures, such as differential contraction of metal parts, loss of resiliency of packings and gaskets, and congealing of lubricants, would

not be experienced on the gunner's seat because these materials are not present. The materials used in the gunner's seat will not be affected by the low temperatures.

Sunshine--The materials used in the gunner's seat system were reviewed with regard to degradation by sunshine as specified in Method 505, Procedure 1 of MIL-STD-810. Polyester fabric and webbing used in the seat cover and restraint system are the materials most likely to be affected by sunshine. Some fading of color can be expected; the degree of fading depends upon the color selected. Some material degradation would occur over the normal service life of the fabric and webbing, but sufficient safety margins are designed into the material that system safety would not be compromised.

Humidity--The materials used in the gunner's seat system were reviewed to determine their resistance to the effects of exposure to a warm, highly humid atmosphere such as that specified in Environmental Test Method 507 of MIL-STD-810. Hydroscopic materials are generally sensitive to humidity. Moisture penetration can result in corrosion or swelling, which destroys functional utility, causes loss of strength, and changes mechanical properties. Hydroscopic materials, other than the seat fabric and webbing, are not used in the gunner's seat. The polyester fabric and webbing will withstand humidity for prolonged periods without deterioration or loss of strength. Other seat materials do not appear to be sensitive to humidity.

Fungus--The gunner's seat materials were reviewed to determine if any contained nutrients to fungus. None of the materials listed in Environmental Test Method 509 of MIL-STD-508 are used in the seat construction, and none of the materials used are suspected of containing fungus nutrients.

Salt Fog--Many of the materials used in the construction of the gunner's seat are subject to corrosion when exposed to salt fog such as that specified in Environmental Test Method 509 of MIL-STD-810. However, these materials are adequately treated and painted to resist the effects of salt fog.

Dust--The ability of the gunner's seat system to operate when subjected to dust environment such as that specified in Environmental Test Method 510 of MIL-STD-810 was reviewed. Mechanical operation of the seat is required only during a crash impact. At this time the seat must move freely in the direction of the impact and be restrained by the load-limiting extending energy attenuators. Moving parts consist of rod end bearings and energy attenuators. The yielding cable and wire bending energy attenuator would not be affected by a coating of dust particles. The telescoping-tube type energy attenuator and the rod-end bearings could be affected. These components, however, are sealed to prevent entry of dust particles.

Vibration--The gunner's seat system was reviewed for areas which may be subject to fatigue, failure, or malfunction as a result of vibration similar to that specified in Vibration Test Method 514, Procedure 1 (Parts 1, 2, and 3) of MIL-STD-810. The quick release pins with ball type stops, which are subject to vibration failure, were replaced with improved quick release pins with cam type stops. The only other seat component which could be affected by vibration is the telescoping tube/torsion wire energy attenuator. This device will require qualification testing before operational use.

Mechanical Shock--The gunner's seat system was reviewed for areas which could fail if subjected to the mechanical shock environment normally encountered in handling and transportation. The environment, specified in Shock Test Method 510 of MIL-STD-810, was considered. The seat is designed to withstand crash impact loads, and when the seat is packaged for shipment in accordance with the gunner's seat military specification, it can be expected to withstand drops of the severity specified.

Maintainability Analysis

Review of the details and installation procedure for the crashworthy gunner's seat reveals no major maintenance problems. Standard hardware is used at attached points, and no special tools are required for maintenance. The seat design employs quick disconnect devices at key attaching points, which permits rapid and efficient seat stowage by one man. Replaceable components (energy attenuators, cables, head rests, and seat fabric) are accessible and replaceable at organizational level.

Reliability Analysis

The CH-47 crashworthy gunner's seat assembly has been subjected to an analysis of assembly and component failure modes and their effects. Each mode of failure has been evaluated to determine its criticality with respect to safety, mission accomplishment, component removal, or corrective maintenance demand. These data have been documented on Boeing Failure Mode Effects and Criticality Analysis (FMECA)forms which follow. The crashworthy gunner's seat assembly is expected to have 0.030 failures per 1,000 component hours. However, most of these failures are expected to be caused by abuse and handling during seat removal, storage, and installation, and would be repaired before use by gunners.

SEAT FRAME ASSEMBLY

ITEM IDENTIFICATION NAME DRAWING REFERENCE IDENTIFICATION CODE	FUNCTION	FAILURE MODE	CAUSE OF FAILURE	DETECTED DURING	FAILURE DETECTION METHOD	FAILURE EFFECT: COMPONENT OR FUNCTIONAL ASSEMBLY	FAILURE EFFECT: NEXT HIGHER SUBSYSTEM	FAILURE EFFECT: TOTAL SYSTEM	FAILURE EFFECT: OTHER COMPONENTS/ SUBSYSTEMS
SEAT - FRAME ASSY. SK-26266-1 TUBE SK-26266-2 TUBE SK-26266-3 TUBE SK-26266-4 TUBE SK-26266-6 TUBE SK-26266-8 TUBE SK-26266-9 ELBOW SK-26275-1	The seat frame assembly is designed to absorb and transmit all normal and abnormal forces imposed on the occupant to the energy absorbing devices of the seat assembly.	Cracked Scratched Bent	Normal Use and Abuse During Removal Storage & Installation	Use, Installation and Removal	Visual and Functional	Remove or Repair Defective Parts	No Effect	No Effect	No Effect

ITEM IDENTIFICATION NAME DRAWING REF.	FAILURE MODE	CRITICALITY SAFETY	CRITICALITY MISSION	CRITICALITY COMPONENT REMOVAL REQUIRED	CORR MAINT REQ	DESIGN PROVISIONS WHICH REDUCE FAILURES/CRITICALITY	FAILURE RATE PER 1000 COMPONENT HOURS	MTBF	RECOMMENDATIONS/REMARKS
SEAT - FRAME ASSY. SK-26266-1	Scored	Safe	None	No	Yes				Frame Assy. welded per MIL-W-6[illegible] with 4043 Al. Aly. Wire.
TUBE SK-26266-2 1.250 Dia. x .065 Wall Al. Alloy	Scratched	Safe	None	No	Yes	SUB. TOTAL	.004	250,000	
TUBE SK-26266-3 1.250 Dia. x .065 Wall	Bent	Safe	None	Yes	Yes				
TUBE SK-26266-4 1.250 Dia. x .065 Wall									
TUBE SK-26266-6 1.50 Dia. x .095 Wall									
TUBE SK-26266-8 1.250 Dia. x .065 Wall									
TUBE SK-26266-9 1.250 Dia. x .065 Wall									
ELBOW SK-26275-1									

FABRIC ASSEMBLY AND DETAIL

ITEM IDENTIFICATION NAME DRAWING REFERENCE IDENTIFICATION CODE	FUNCTION	FAILURE MODE	CAUSE OF FAILURE	DETECTED DURING	FAILURE DETECTION METHOD	FAILURE EFFECT: COMPONENT OR FUNCTIONAL ASSEMBLY	FAILURE EFFECT: NEXT HIGHER SUBSYSTEM	FAILURE EFFECT: TOTAL SYSTEM	FAILURE EFFECT: OTHER COMPONENTS/ SUBSYSTEMS
FABRIC ASSEMBLY, SEAT SK-26267-1									
FABRIC, SEAT PAN SK-26267-2 FABRIC SEAT BACK AND POUCH SK-26267-3 FABRIC, SEAT POUCH CLOSING FLAP SK-26267-4 BELT, WEBBING, VERTICAL SUPPORTS SK-26267-5 BELT, WEBBING, HORIZONTAL SUPPORTS SK-26267-6	To Comfortably and Safely Support the Occupant During All Modes of Flight	Worn Torn Soiled	Normal Use Or Abuse	Normal Use	Visual/ Functional Inspection	Removal or Repair of Discrepant Parts Required Before Flight	No Effect	No Effect	No Effect
STRIP SK-26267-7 STRIP SK-26267-8	To Secure the Fabric Seat Pan to the Seat Frame Assy.	Loose	Attaching Screws Loose Or Missing	Normal Use	Visual Or Functional Inspection	Tighten Or Replace Screws	No Effect	No Effect	No Effect
FITTING ASSY. SK-26083-3	To Secure the Vertical Support Webbing to the Top of the Seat Frame Assy.	Scratched Bent	Abuse	Use		Replace Before Flight	No Effect	No Effect	No Effect

FABRIC ASSEMBLY AND DETAIL (SK-26267-1)

ITEM IDENTIFICATION: NAME DRAWING REF.	FAILURE MODE	CRITICALITY: SAFETY	CRITICALITY: MISSION	CRITICALITY: COMPONENT REMOVAL REQUIRED	CORR MAINT REQ	DESIGN PROVISIONS WHICH REDUCE FAILURES/CRITICALITY	FAILURE RATE PER 1000 COMPONENT HOURS	MTBF	RECOMMENDATIONS/REMARKS
FABRIC ASSY. SEAT SK-26267-1									All Sewing to be in accordance with FED. STD. No. 751A.
FABRIC, SEAT PAN SK-26267-2	Worn	Safe	None	Yes	Yes		.002	506,000	Fabric MIL-C-7219 Type III (Light Grey)
FABRIC, SEAT BACK AND POUCH SK-26267-3	Torn	Safe	None	Yes	Yes		.001	1,000,000	
FABRIC, SEAT POUCH CLOSING FLAP SK-26267-4							.001	1,000,000	
BELT, WEBBING, VERTICAL SUPPORT SK-26267-5	Soiled	Safe	None	No	Yes		.001	1,000,000	.065 x 2.00 x 62.00LG 9000 LB UTS Polyester Webbing
BELT WEBBING HORIZONTAL SUPPORTS SK-26267-6							.001	1,000,000	.065 x 2.00 x 21.00LG 9000 LB UTS Polyester Webbing
STRIP SK-26267-7 STRIP SK-26267-8	Loose	Safe	None	No	Yes		.001	1,000,000	.063 x .50 x 10.62LG, 2024-T3 Al. Aly. QQA-250/5 .063 x .50 x 12.38LG, 2024-T3 Al. Aly. QQA-250/5
FITTING ASSY. SK-26083-3	Bent	Safe	None	Yes	Yes		.001	1,000,000	
						SUB. TOTAL	.008	125,000	

ITEM IDENTIFICATION NAME DRAWING REFERENCE IDENTIFICATION CODE	FUNCTION	FAILURE MODE	CAUSE OF FAILURE	DETECTED DURING	FAILURE DETECTION METHOD	FAILURE EFFECT: COMPONENT OR FUNCTIONAL ASSEMBLY	FAILURE EFFECT: NEXT HIGHER SUBSYSTEM	FAILURE EFFECT: TOTAL SYSTEM	FAILURE EFFECT: OTHER COMPONENTS/ SUBSYSTEMS
TOGGLE LINK ASSY. SK-26276-1	Secures the seat to the cabin ceiling and is used to adjust tension on floor cables.	Loose	Improper Adjustment	Use	Visual And Functional Inspection	Adjust	No Effect	No Effect	No Effect
HOUSING ASSEMBLY SK-26268-4	Contains Rollers and E/A Wire.	Dirty	Normal Use	Use	Visual And Functional Inspection	Clean	No Effect	No Effect	No Effect
ROLLERS SK-26272-1 WIRE, E/A SK-26271-1	To guide and restrict E/A wire as required to absorb crash loads.	Dirty	Normal Use	Use	Visual And Functional Inspection	Clean	No Effect	No Effect	No Effect
CLIP - TUBE SK-26273-1	Secures the toggle link, housing and rollers to the crashworthy seat frame assembly.	Loose	Normal Use	Use	Visual And Functional Inspection	Tighten	No Effect	No Effect	No Effect
HEAD REST SK-26274-6	To provide a head rest and to minimize any head loads experienced by the seat occupant.	Dirty Worn	Normal Use	Use	Visual And Functional Inspection	Clean Or Repair	No Effect	No Effect	No Effect

ITEM IDENTIFICATION NAME DRAWING REF.	FAILURE MODE	CRITICALITY SAFETY	CRITICALITY MISSION	CRITICALITY COMPONENT REMOVAL REQUIRED	CORR MAINT REQ	DESIGN PROVISIONS WHICH REDUCE FAILURES/CRITICALITY	FAILURE RATE PER 1000 COMPONENT HOURS	MTBF	RECOMMENDATIONS/REMARKS
TOGGLE LINK ASSY. SK-26276-1	Jammed Bent	Safe Safe	None None	Yes Yes	Yes Yes	Designed for ease of installation and adjustment.	.001	1,000,000	
HOUSING ASSY. SK-26268-4	Dirty	Safe	None	No	Yes		.0005	2,000,000	
ROLLERS SK-26272-1	Dirty	Safe	None	No	Yes		.001	1,000,000	
WIRE E/A SK-26271-1	Dirty	Safe	None	No	Yes		.0005	2,000,000	.110 dia. x 46.0 long music wire spring steel QQ-W-470.
CLIP - TUBE SK-26273	Loose	Safe	None	No	Yes		.001	1,000,000	
HEAD REST SK-26274-6	Dirty Worn	Safe Safe	None None	No Yes	Yes Yes		.001	1,000,000	
						SUB. TOTAL	.005	200,000	

ITEM IDENTIFICATION NAME DRAWING REFERENCE IDENTIFICATION CODE	FUNCTION	FAILURE MODE	CAUSE OF FAILURE	DETECTED DURING	FAILURE DETECTION METHOD	FAILURE EFFECT: COMPONENT OR FUNCTIONAL ASSEMBLY	FAILURE EFFECT: NEXT HIGHER SUBSYSTEM	FAILURE EFFECT: TOTAL SYSTEM	FAILURE EFFECT: OTHER COMPONENTS/ SUBSYSTEMS
REEL ASSEMBLY, SHOULDER HARNESS AND SEAT BELT 0107119-47	The restraint system must hold the occupant effectively on the seat free from the possibility of collision with surrounding structure. It must provide the proper restraint for the upper torso without itself injuring the occupant.	Worn Chafed Slipping Binding Dirty	Normal Use And Or Improper Handling	Normal Use	Visual Or Functional Operation	Removal Or Repair of Discrepant Parts Required Prior to Flight	No Effect	No Effect	No Effect
GUIDE ASSEMBLY SK-26274-1	To guide the harness straps from the reel, through the seat, and over the occupants' shoulders without restriction.	Broken Bent	Improper Handling	Normal Use	Visual Or Functional Operation	Replace Discrepant Parts	No Effect	No Effect	No Effect

ITEM IDENTIFICATION NAME DRAWING REF.	FAILURE MODE	CRITICALITY SAFETY	CRITICALITY MISSION	CRITICALITY COMPONENT REMOVAL REQUIRED	CORR MAINT REQ	DESIGN PROVISIONS WHICH REDUCE FAILURES/CRITICALITY	FAILURE RATE PER 1000 COMPONENT HOURS	MTBF	RECOMMENDATIONS/REMARKS
REEL ASSY. SHOULDER HARNESS AND SEAT BELT 0107119-47	Worn Chafed Slipping Binding Dirty	Safe Safe Marginal Safe Safe	None None None None None	Yes Yes Yes Yes No	Yes Yes Yes Yes Yes		.005	200,000	4 Reels per seat assembly.
GUIDE ASSY. SK-26274-1	Torn	Safe	None	Yes	Yes	The inside dia. of the polyvinyl chloride tubing is sprayed with Teflon to prevent friction or chafing of the shoulder harness.	.001	1,000,000	2 Guides per seat assembly.
						SUB. TOTAL	.006	166,666	

ITEM IDENTIFICATION NAME DRAWING REFERENCE IDENTIFICATION CODE	FUNCTION	FAILURE MODE	CAUSE OF FAILURE	DETECTED DURING	FAILURE DETECTION METHOD	FAILURE EFFECT COMPONENT OR FUNCTIONAL ASSEMBLY	NEXT HIGHER SUBSYSTEM	TOTAL SYSTEM	OTHER COMPONENTS/ SUBSYSTEMS
ENERGY ATTENUATOR SK26265 CYLINDER (AL. ALY. TUBING)	A compressive type of absorber that is structurally adequate to absorb the impact loads while permitting the seat to stroke to the floor.	Scored Scratched	Normal Use And Abuse During Seat Removal, Storage And Installation	Seat Use, Removal And Installation	Visually And Functional Operation	Repair	No Effect	No Effect	No Effect
ROD END BEARINGS	To provide an efficient means of securing the energy attenuator to the seat and floor throughout all modes of movement	Worn				Replace	No Effect	No Effect	No Effect

ENERGY ATTENUATOR

ITEM IDENTIFICATION NAME DRAWING REF	FAILURE MODE	CRITICALITY SAFETY	MISSION	COMPONENT REMOVAL REQUIRED	CORR MAINT REQ	DESIGN PROVISIONS WHICH REDUCE FAILURES/CRITICALITY	FAILURE RATE PER 1000 COMPONENT HOURS	MTBF	RECOMMENDATIONS/REMARKS
ENERGY ATTENUATOR SK26265-1									2 Per Seat Stroking Load - 1300 ± 30 Lbs. Compression Load - 840 Lbs. Min. Tension Stroke - 10.0 Min. Compression Stroke - 0.00 Min.
	Scored	Safe	None	No	Yes				
CYLINDER (AL. ALY TUBING	Scratched	Safe	None	No	Yes		.001	1,000,000	
ROD END BEARINGS	Worn	Safe	None	Yes	Yes		.003	333,333	2 Per Attenuator
						SUB. TOTAL	.004	250,000	

CABLE ASSEMBLY (SK-26264-1)

ITEM IDENTIFICATION: NAME, DRAWING REFERENCE, IDENTIFICATION CODE	FUNCTION	FAILURE MODE	CAUSE OF FAILURE	DETECTED DURING	FAILURE DETECTION METHOD	FAILURE EFFECT: COMPONENT OR FUNCTIONAL ASSEMBLY	FAILURE EFFECT: NEXT HIGHER SUBSYSTEM	FAILURE EFFECT: TOTAL SYSTEM	FAILURE EFFECT: OTHER COMPONENTS/SUBSYSTEMS
CABLE ASSY. SK-26264-1	To provide vertical, lateral and horizontal seat stability								
CABLE SK-26264-2		Chafed	Normal Use And Abuse During Seat Removal, Storage And Installation	Seat Use, Removal And Inst'n	Visually And Functional Operation	Replace	No Effect	No Effect	No Effect
TENSOL PIN TL844C	To secure the seat cable assy. to the aircraft floor mount	Worn							
FORK END TERMINAL MS 20667-3 MS 20667-4	To provide a means of securing the cable to the seat and the aircraft floor mounts	Worn							

CABLE ASSEMBLY (SK-26264-1) SHEET 12 OF 12

ITEM IDENTIFICATION NAME DRAWING REF.	FAILURE MODE	CRITICALITY SAFETY	CRITICALITY MISSION	CRITICALITY COMPONENT REMOVAL REQUIRED	CORR MAINT REQ	DESIGN PROVISIONS WHICH REDUCE FAILURES/CRITICALITY	FAILURE RATE PER 1000 COMPONENT HOURS	MTBF	RECOMMENDATIONS/REMARKS
CABLE ASSY. SK-26264-1						Cable assy. annealed to produce high elongation energy attenuation features.			4 Cables Per Seat Assy.
CABLE SK-26264-2	Chafed	Safe	None	Yes	Yes		.001	1,000,000	
TENSOL PIN TLB 44C	Worn	Marginal	None	Yes	Yes		.001	1,000,000	
FORK END MS 20667-4	Worn	Safe	None	Yes	Yes		.0005	2,000,000	
FORK END MS 20667-3	Worn	Safe	None	Yes	Yes		.0005	2,000,000	
						SUB. TOTAL	.003	333,333	
						SEAT FRAME ASSY.	.004	250,000	
						FABRIC ASSY. & DETAIL	.008	125,000	
						TOGGLE/HOUSING/ROLLERS	.005	200,000	
						SHOULDER/SEAT BELTS	.006	166,666	
						ENERGY ATTENUATOR	.004	250,000	
						CABLE ASSEMBLY	.003	333,333	
						TOTAL	.030	33,333	

CONCLUSIONS

Detailed conclusions have been presented at the end of each section. The significant conclusions reached on the total program are summarized here for seat configuration, restraint system, armor, and seat specifications.

SEAT CONFIGURATION

A crashworthy gunner's seat must provide the best crashworthy features, yet must not jeopardize the gunnery functions. To perform the side-facing gunnery operation, the gunner must be in a side-facing seat. Yet, a seat facing sideways is oriented in the direction of least crashworthiness due to the low human tolerance to the lateral acceleration experienced during forward impacts. A seat which can face the side for gunnery operations and can face forward for crash impacts is ideal. Such an arrangement can be achieved by placing the seat on a swivel.

RESTRAINT SYSTEM

For a seat to be crashworthy the first requirement is for the occupant to be restrained to the seat. If restrained to the seat, the gunner cannot perform the gunnery functions unless a complex, motorized, gimballed seat is provided. The compromise is to use a fixed seat and provide a retractable restraint system. Reels at the lap belt and shoulder strap anchorage will permit the gunner to move away from the seat to perform the gunnery function, yet will instantly retract to restrain the gunner when he sits down. A conventional lap belt and Y-type shoulder strap restraint system can be used. The only variation is the addition of a thigh strap which prevents the system from being displaced during gunnery motions.

ARMOR

A fully armored seat does not appear to be practical for a gunner. To be practical the seat must be fixed and the sides must be open to allow for gunner motions; seat pan and back armor are the only armor permitted on the seat. Partial back armor can be used in conjunction with body armor. Using a modular-armor seat appears to be a more practical approach than an integral-armor seat because of the minimum armor permitted.

GUNNER'S SEAT MILITARY SPECIFICATION

The draft military specification for crashworthy gunner's seats, prepared by the Eustis Directorate and with the change recommendations resulting from this investigation program, is a practical specification for the design of crashworthy gunner seats.

RECOMMENDATIONS

MODIFICATIONS TO DOCUMENTS

A requirement of the crashworthy gunner's seat development program was for the contractor to recommend appropriate modifications to the proposed draft military specification MIL-S-XXXX (AV), Seat, Crashworthy Helicopter Gunner, General Specification For, and USAAMRDL TR 71-22, Crash Survival Design Guide. The following modifications to these documents are recommended.

RECOMMENDATIONS FOR CHANGES TO GUNNER'S SEAT DRAFT MILITARY SPECIFICATION

The gunner's seat draft military specification is reproduced on the following pages with the modifications that are recommended. The entire specification is reproduced including the figures, which were unaffected by the modifications. The modifications are noted by crosshatching those portions to be deleted (/////) and underlining portions which are added (____). The changes are explained at the end of the specification. Each change is keyed to its explanation by a number in the margin.

PROPOSED DRAFT MILITARY SPECIFICATION

SEAT, CRASHWORTHY HELICOPTER

GUNNER, GENERAL SPECIFICATION FOR

1. SCOPE

1.1 This specification establishes the performance, design, development and test requirements for standard lightweight side-facing, crashworthy seats for use by gunners in utility- and cargo-type helicopters.

1.2 Classification. ~~Types~~ Gunner seats shall be of the following types as specified (see 6.2):

Type I	Unarmored seat
Type II	Seat with integral armor bucket
Type III	Seat with modular armor

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids or request for proposal form a part of the specification to the extent specified herein.

SPECIFICATIONS

FEDERAL

V-T-295	Thread, Nylon
QQ-P-416	Plating, Cadmium (Electrodeposited)
QQ-Z-325	Zinc Coating, Electrodeposited, Requirements For
PPP-B-601	Boxes, Wood, Cleated-Plywood
PPP-B-621	Boxes, Wood, Nailed and Lock-Corner
PPP-B-636	Boxes, Fiberboard

MILITARY

AN-7516	Fitting-Cargo Airplane Tiedown
MIL-P-116	Preservation, Methods of
MIL-D-1000	Drawings, Engineering and Associated Lists
~~MIL-W-4088~~	~~Webbing, Textile, Woven, Nylon~~
MIL-W-25361	Webbing, Textile, Polyester, Low Elongation 1
~~MIL-C-5061~~	~~Cloth, Nylon, Raschel Net~~

MIL-A-8625	Anodic Coatings, for Aluminum And Aluminum Alloys
MIL-R-8236	Reel, Shoulder Harness, Inertia Lock
MIL-W-8604	Welding of Aluminum Alloys: Process for
MIL-F-8905	Adapter, Tie Down, Aircraft Floor
~~MIL-A-21103~~	~~Adapters, Quick-Disconnect, Passenger Seat To Floor~~ (2)
MIL-W- 5205	Welding, Gas Metal-Arc & Gas Tungsten-Arc, Aluminum Alloys, Readily Weldable for Structures, Excluding Armor

STANDARDS

FEDERAL

FED-STD-595	Colors
FED-STD-751	Stitches, Seams, and Stitchings

MILITARY

MIL-STD-22	Welded-Joint Designs
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of US Military Property
MIL-STD-143	Specifications and Standards Order of Precedence for the Selection of
MIL-STD-471	Maintainability Demonstration
MIL-STD-785	Reliability Program for Systems & Equipment Development & Production
MIL-STD-831	Test Reports, Preparation of
MIL-STD-889	Dissimilar Metals
MIL-STD-1186	Cushioning, Anchoring, Bracing, Blocking, and Waterproofing; With Appropriate Test Methods
MIL-STD-1261	Welding Procedures for Constructional Steels
MIL-STD-1290	Light-Fixed- and Rotary-Wing Aircraft Crashworthiness
MIL-STD-1333	Aircrew Station Geometry for Military Aircraft
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MS26504	Plate-Anchor, Aircraft Troop Seat

PUBLICATION

MILITARY HANDBOOK

MIL-HDBK-5	Metallic Materials and Elements for Aerospace Vehicle Structures

REPORTS

USAAMRDL TR 71-22	Crash Survival Design Guide
USAAMRDL TR 71-41A,-41B	Survivability Design Guide for US Army Aircraft
USANLABS TR 72-51-CE	Body Size of Soldiers-US Army-Anthropometry 1966

(Copies of specifications, standards, publications, and reports required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Design characteristics of seat system.--Occupant protection and survival in aircraft accidents shall be a primary consideration in seat system design. Such protection requires that both the seat system and the occupant be retained in the same relative position within the aircraft throughout the 95th percentile potentially survivable accident (see 6.3.5) without the occupant being subjected to conditions in excess of human tolerance (see 6.3.9). The seat system shall also provide maximum comfort and ease of removal. ~~The area above, beneath, and to each side of the seat bottom pan shall allow rapid ingress and egress.~~ Seat suspension or support systems shall not interfere with rapid ingress or egress. Braces, legs, cables, straps, and other structures shall be designed to prevent snagging on troop and gunner equipment or cause tripping or encumbrance during ingress, egress or gunnery operations. The occupant restraint subsystem, the means of attaching the seat to the basic aircraft structure, any seat cushions required (see 6.2), and any armor required (see 6.2) are parts of the seat system. Another primary design consideration is that the seat system permit the occupant to perform his gunner tasks unencumbered while restrained ~~in~~ to the seat. 3 4

3.1.1 Ballistic Protection.--Type II and Type III seats shall provide the occupant with the following ballistic protection:

~~1. No Penetrations,~~ V20, 7.62mm AP (Armor Piercing), 100 yds 2550 ±50 FPS, At 0° Obliquity 5

Type II seats shall provide the specified level of ballistic protection with an integrally armored seat bucket, i.e. a seat bucket structure fabricated of armor. Type III seats shall provide the specified level or ballistic protection using a modular armor concept, i.e. armor panels secured to the seat bucket structure. ~~Although~~ Type II and Type III seats shall 6 be designed to be convertible for use either as an armored or unarmored seat~~,~~. Seat strength (see 3.4.7) shall be based on

the armored configuration. USAAMRDL TR 71-41, Survivability Design Guide For U.S. Army Aircraft, shall be used as a guide during the design of occupant ballistic protection.

3.1.2 Removal. All seats shall be so designed that they may be capable of being removed quickly and easily by ~~one man~~ two men in a period of not to exceed ~~two~~ ten minutes. Removal (7) of the seat shall not require the use of special tools or special equipment. ~~or the removal of parts.~~

3.1.3 Seat bottom and back.--The seat bottom and back shall be fabricated to provide maximum comfort and durability. They shall be tailored to follow the general contours of the occupant's body and to distribute suitably the acting loads to the seat frame. Seat bottoms made of fabric shall be provided with means for tightening the seat bottom to correct for ~~any~~ sagging due to use. Sufficient clearance between fabric seat bottoms and any ~~supporters~~ under seat structure used shall be (8) provided in order that the seat bottom will not contact the ~~support~~ structure under specified load. Seat bottoms shall be designed to minimize occupant dynamic overshoot and/or submarining (see 6.3.7 and 6.3.6).

~~3.1.4 Leg supports.--When leg supports are used, the base~~ (9) ~~of the legs shall contain fittings in accordance with MIL-A-21193. Fittings shall be capable of attaching the seats securely to the stud of anchor plate shown in MS26504 and the stud of the tie-down fitting shown in MIL-A-8905 or AN-7516. The anchor plate and the tie-down fitting are installed in the airplane flush with the floor surface. The leg fittings shall~~ (10) ~~be of the quick-release type. The release shall be capable of being actuated at the base of the leg. The legs shall be capable of a small movement in the fore and aft direction of the location of the floor fittings.~~

3.1.5 Attachment.--Whenever feasible and practical, seats shall be ~~ceiling and floor mounted. The various acceptable means of attaching seats to the cabin interior are ranked below in order of descending desirability.~~

~~(1) Ceiling and floor mounted.~~
~~(2) Ceiling, wall, and floor mounted.~~
~~(3) Floor mounted.~~
~~(4) Wall and floor mounted.~~
~~(5) Wall mounted.~~

suspended from the ceiling with energy attenuators. The seat (11) pan should be stabilized in a manner that does not require the use of energy attenuators in series (i.e. attenuators above and below seat) for vertical loading.

Acceptable means of attaching seats to the cabin interior are ranked below in order of desirability, with the assumption that the ceiling structure and side frames are of sufficient strength and integrity to support the load with acceptable deflection during impact. 11

1) Ceiling suspended with attenuator and wall stabilized

2) Suspended from the ceiling with attenuator and floor stabilized 11

3) Floor mounted

4) Wall mounted

5) Ceiling and floor mounted (vertical energy attenuators above and below seat).

3.1.6 Occupant restraint subsystem.--Seats shall provide an integral, self-retracting and self-locking restraint harness complying with the criteria of 3.3.2 and 3.4.11 for the seat occupant.

3.1.7 Orientation.--Side facing seats shall be designed to permit rapid rotation to a forward- or aft-facing position to align the gunner in the direction of highest human tolerance to predominantly forward crash impacts. Detents shall be provided to maintain the seat in a side-facing direction and shall automatically release when a 20 ±5 pound load is applied to the periphery of the seat. 12

3.1.8 Accommodations.--The seat shall be designed to accommodate through the range of a 5th-percentile occupant without equipment to a 95th percentile gunner with survival vest and cold weather clothing and to a 95th percentile troop with full combat assault equipment and a medium rucksack or butt pack holding combat assault loads. 13

3.2 Preproduction.--Unless otherwise specified (see 6.2), this specification requires a complete seat system(s) for preproduction examination and testing (see 4.3). The preproduction test sample(s) shall conform to all requirements of this specification. The preproduction test sample(s) shall be identical with the production items in accordance with the terms of the contract. Approval of the preproduction test sample(s) shall not relieve the supplier of the responsibility to furnish equipment in accordance with this specification.

3.3 Materials.--Materials shall be as specified herein. When specifications and standards are not specifically

designated, selection of materials and processes shall be in accordance with MIL-STD-143. The seat shall be built of materials which do not support the growth of fungus. Materials that are nutrients for fungi shall not be used when it is feasible to avoid them; where used and not hermetically sealed, they shall be treated with a fungicidal agent acceptable to the procuring activity.

3.3.1 Seat bottom and back.--Cloth materials for the seat back and bottom shall be vat-dyed a color selected by the procuring activity. The color shall conform to FED-STD-595. All thread and stitches used for sewing seat back and seat bottom shall be in accordance with V-T-295 and FED-STD-751, type 301, respectively.

3.3.2 Occupant restraint ~~harness~~ subsystem.--Metal materials of all restraint ~~harness~~ subsystem fittings shall be fabricated from materials with characteristic elongation values of not less than 10 percent prior to failure. Strap webbing shall be constructed of a material that will not allow harness slackness due to slippage.

3.3.3 Critical members.-- All critical compressive structural members shall be fabricated from ductile materials having a characteristic value of not less than 5 percent elongation. All critical tensile and bending members shall be capable of elongating a mimimum of 10 percent prior to failure.

3.3.4 Flammability and toxicity.--Materials which will support a self-sustained combustion and materials which, when burned or exposed to high temperatures, give off toxic fumes shall be prohibited.

3.4 Construction.--The inside surface and all exposed edges of the seat shall be free from projections and sharp edges that could catch or damage by abrasion the clothing or the equipment of the occupant. The exterior surfaces of the seat shall be free from both sharp edges and corners, or any other projections that could scratch the hands or clothing of the occupant.

3.4.1 Standard parts.--MS or AN standard parts shall be used wherever they are suitable for the purpose, and shall be identified on the drawings by their part numbers. Commercial parts such as screws, bolts, and nuts may be used provided they possess suitable properties and are replaceable by MS or AN standard parts without alteration.

3.4.2 Interchangeability of parts.--Components shall be functionally and dimensionally interchangeable (without

requiring modification for replacement) with similar components furnished under the same contract or order.

3.4.3 Dissimilar metals.--Unless components are suitably protected against electrolytic corrosion, contact between dissimilar metals shall not be used where it is feasible to avoid it. Dissimilar metals are defined in MIL-STD-889.

3.4.4 Protective treatment--When materials that are subject to corrosion in salt air or any other atmospheric condition liable to occur during service usage (see 3.7) are used in the construction of the seat, they shall be protected against such corrosion in a manner that will in no way prevent compliance with the performance of the seat system. The use of any protective coating that will crack, chip, or scale with age or extremes of atmospheric conditions shall be prohibited.

3.4.5 Finishes--Aluminum alloy parts shall be anodized in accordance with type II of MIL-A-8625. Magnesium alloy parts shall be treated in accordance with MIL-M-3171. Non-corrosive-resistant steel parts shall be either cadmium plated in accordance with QQ-P-416 or zinc plated in accordance with QQ-Z-325.

3.4.6 Joining and fastening.--Riveting and welding may be used for assembling the component parts fabricated from materials which are suitable for this type of construction. Fittings and joints requiring disassembly for installation and removal of the seat from the aircraft, or disassembly of the component parts of the seat system, shall be bolted.

3.4.7 Structural strength and deformation.--Longitudinal, lateral, and upward seat structural strength and deformation requirements stated herein are based on the 95th percentile clothed occupant weight (see 6.3.2) plus the weight of the seat and any equipment and/or armor attached to or carried in the seat. The structural strength of Type II and Type III seat designs shall be based on the armored configuration. Downward seat structural strength and deformation requirements specified herein are based on the effective weight of the 50th percentile clothed occupant ~~(see 6.3.10)~~ (see 6.3.2) plus the weight of that portion of the seat which must stroke during vertical crash force attenuation (see 3.4.8). This necessitates that the seat crash force attenuation mechanism be switched, or adjusted, when converting from the armored to unarmored (or vice versa) due to the change in the mass of the portion of the seat which strokes during crash force attenuation (see 3.4.8). 14

3.4.7.1 Longitudinal strength and deformation.--Controlled deformation of seats shall not exceed 10 inches

displacement measured along the longitudinal (roll) axis of the aircraft or shall not permit occupant contact with surrounding structure.

3.4.7.1.1 Forward load.--The seat shall have a characteristic static forward load deflection curve measured along the longitudinal (roll) axis of the aircraft which rises to the left and above the base area and extends into the acceptable seat failure area shown on Figure 1. Acceptable and unacceptable sample static forward load-deflection curves are illustrated in Figure 1.

3.4.7.1.2 Aftward loads.--The seat strength shall be not less than 12G (see 6.3.4) for aftward loads measured along the longitudinal (roll) axis of the aircraft.

3.4.7.2 Lateral strength and deformation.--The seat shall have a characteristic static lateral load deflection curve measured along the lateral (pitch) axis of the aircraft seat failure area shown on Figure 2.

3.4.7.3 Vertical strength and deformation.--Human tolerance to vertical impact (see 6.3.9) limits the acceptable forces measured along the vertical (yaw) axis of the aircraft. ~~Seats suspended from the aircraft ceiling may be designed to peak vertical loads as low as 40% of the peak vertical design loads for floor and wall mounted seats if the procuring activity concurs in the contractor's substantiating data.~~ (15)

3.4.7.3.1 Downward load.--The seat shall have a downward load-deflection curve measured along the vertical (yaw) axis which falls within the acceptable area on Figure 3. The seat ultimate failure value shall not be less than 25G after the seat has stroked through the available seat stroking distance, unless the seat pan is permitted to bottom out on floor structure. (16)

3.4.7.3.2 Upward load--The design load factor (G) shall not be less than 8G parallel to the vertical (yaw) axis.

3.4.7.4 Rotating seat loads--Gunner seats capable of rotation shall have strength and deformation characteristics specified for forward loads (see 3.4.7.1.1) for all sides (front, back or side) capable of being oriented towards the front of the aircraft. (17)

3.4.8 Crash force attenuation along vertical (yaw) axis.--The seat system to perform its intended occupant retention function, shall possess sufficient energy-absorption capacity and structural strength to reduce the occupant velocity relative to the cabin floor structure to zero before structural failure of the seat occurs, and to prevent the 5th

through 95th percentile occupants (see 6.3.1) from experiencing decelerations in excess of human tolerance (see 6.3.9) during crash pulses of the severity of up to and including the 95th percentile potentially survivable accident pulse (see 6.3.5). Energy shall be absorbed either by plastic deformation of the seat structure or by load-limiting devices (see 6.3.8) or a combination of both. The energy-absorption mechanism stroke shall be the maximum attainable in the space between the seat bottom and the aircraft floor. In any case, not less than ~~12~~ 14 inches of usable vertical stroking distance shall be provided. Type II and III seats shall have a separate energy absorption device for both the armored and unarmored configurations. The two devices shall be interchangeable so that when the seat is changed from one armored configuration to the other, the energy absorbers can also be changed with a minimum amount of effort. The load level for each energy absorber device shall be determined in accordance with the provisions of 3.4.7. 18

3.4.8.1 Crash Force Attenuation Along Other Axis--Energy attenuating provisions are not mandatory for other than the vertical axis; however, it is preferred that such be provided to reduce seat loads and thereby minimize seat weight. 19

3.4.9 Seat attachments.--Provisions shall be made for the seat system to be attached to the basic aircraft structure with connectors of sufficient strength to preclude attachment failure under the maximum loads specified herein, and under all conditions as specified in 4.5. These seat attachments shall be designed to provide occupants with an obvious warning whenever seats are not entirely locked in place.

3.4.10 Cushions--Unless otherwise specified (see 6.2), seat cushions shall be provided for all seats in which the absence of such cushions would either allow occupant contact with injurious components during deformation of the seat, or detract from the effort to design a comfortable seat for the occupant. Seat cushions provided shall have inherent flotation characteristics on water and be designed primarily for occupant comfort, not as a device to absorb crash energy in the vertical direction. The desired crash energy absorption capacity shall be obtained in the seat energy absorber mechanism specified in 3.4.8. Cushions shall be contoured for the human body in a fashion which does not subject the occupant's torso or extremities to constrictions, or localized pressures, that could either cause a reduction in normal body circulatory functions or eventual deterioration of occupant comfort. The thickness of soft, elastic foam-type material required for a comfort cushion shall not exceed 0.5-inch thickness when compressed by the 95th percentile clothed occupant (see 6.3.2). A net-type seat cushion may be used provided it prevents contact between the occupant and the seat pan under vertical

loading as specified in 3.4.7.3, and that its rebound characteristics limit occupant return movement from the point of maximum deformation to 1.5 inches. If net-type cushions are employed, they shall neither permit snagging with occupant clothing or equipment nor inhibit occupant ingress or egress. The perforation size for net-type cushions shall not exceed the size of MIL-C-8061 or an equivalent net. Any cushions provided shall inhibit both occupant submarining (see 6.3.6) and dynamic overshoot (see 6.3.7).

3.4.11 Occupant restraint subsystem.--The seat restraint subsystem shall conform to the configuration in Figure 4. All occupant restraint subsystems shall minimize occupant submarining (see 6.3.6) and dynamic overshoot (see 6.3.7). Lap belts and shoulder straps must retract automatically. ~~and stow in a~~ 20
~~flush position.~~ The restraint harness shall include a lap belt, ~~two side straps~~, a lap belt ~~tiedown~~ positioning strap, two shoulder straps, and a single point of attachment-release with a single-action-release buckle. The attachment-release buckle shall be affixed to the right side of the lap belt. ~~tiedown strap.~~ The shoulder straps shall fully retract independently to a position where the end fittings are easily accessible by reaching over the shoulder. The lap belt shall 21
be capable of connection prior to connecting the shoulder straps. Loops shall not be formed when the restraint system is released. 22

The restraint harness shall be comfortable, light in weight, and easy for the occupant to put on and remove. The restraint harness straps shall provide the occupant as much area as feasible for force distribution in the upper torso and pelvic regions, and still provide for freedom of movement for the gunner to perform his gunner duties. Loss of support of the occupant shall not occur due to straining of the seat energy absorption mechanisms, plastic deformation of the seat, or a combination of both actions.

3.4.11.1 Structural connections.--Safety factors shall be 5 percent and 10 percent for shear and tensile bolts, respectively. Bolts less than 0.25 inch in diameter shall not be used in tensile applications. Riveted joints shall be designed in accordance with MIL-HDBK-5. Quality welding shall be in accordance with MIL-W-6873, MIL-W-8604, MIL-W-45205, MIL-STD-22, and MIL-STD-1261.

3.4.11.2 Strap design loads.--Strength and elongation of restraint harness strap materials shall be as specified in Table 1.

~~TABLE I -- RESTRAINT HARNESS COMPONENTS LOAD-ELONGATION DESIGN AND TEST REQUIREMENTS~~

~~Harness components~~	~~Maximum elongation (inches) (a)~~	~~Minimum load (pounds) (b)~~
~~Shoulder harness~~	~~1.5 (d)~~	~~4,000 (c)~~
~~Lap belt~~	~~2.0~~	~~4,000~~
~~Lap belt tiedown strap~~	~~0.5~~	~~2,500~~
~~Side strap~~	~~0.5~~	~~2,500~~

~~NOTES:~~

~~(a) Total length of harness component tested shall be the same as its length as installed on the seat when adjusted for a 95th percentile clothed occupant (see 3.3.2).~~

~~(b) This load shall be applied in straight tension.~~

~~(c) This represents the total load on two shoulder straps.~~

~~(d) This applies only to shoulder harness exclusive of the webbing wound on the spool of the retractor.~~

TABLE 1. RESTRAINT HARNESS WEBBING
LOAD - ELONGATION DESIGN AND TEST REQUIREMENT

Use	Strap Width (in.)	Thickness (in.±0.010)	Maximum Elong. at Design Load Percent	Design Load (lb)	Ultimate Load (lb)
Lap Belt	2.25	.055	5	4,000	6,000
Double or Single Shoulder Straps-Each	2.00	.055	4	4,000	6,000
[illegible]	1.25 to [illegible]	.055	4	1,000	1,500
NOTE: All loads are applied in straight tension					

(2)

3.4.11.3 Lap belt.--The lap belt centerline shall be 2 to 3 inches forward of the seat reference point. The lap belt anchorage geometry shall be as shown on Figure 5. The lap belt ~~and~~ reel attachments shall be capable of displacing plus or minus 30 degrees vertically. ~~and plus or minus 60 degrees laterally from the normal positions without producing eccentric loads in either the straps or the attachment fittings.~~ The reel and attachments shall be capable of withstanding lateral design load when the webbing is pulling at an angle of plus or minus 60 degrees to the normal plane of the reel attachment. Lap belts must automatically adjust to, and lock at, the occupant's torso size without adjustment fittings. Strap guides shall be provided at each lap belt reel to prevent the strap from twisting on the reel. (24)

3.4.11.4 Shoulder straps.--Shoulder harness anchorage geometry shall be as shown on Figure 6. The anchorage of guide at the top of the seat shall not permit more than 0.5 inch lateral movement of the strap at this point. The shoulder straps shall form an inverted Y at the seat back. An adjuster shall be provided in each strap. (25)

~~3.4.11.5 Lap belt tiedown strap.--The lap belt tiedown strap shall be located on the seat pan centerline between 14 and 15 inches forward of the seat reference point.~~ (26)

3.4.11.6 Strap dimensions.--Dimensions for the restraint harness straps shall be as specified in Table ~~II~~. 1. (23)

~~TABLE III -- DIMENSIONS FOR RESTRAINT HARNESS STRAPS~~ (23)

~~Item~~	~~Minimum width (inches)~~	~~Minimum thickness (inch)~~
~~Lap belt strap~~	~~2.25~~	~~0.055~~
~~Shoulder harness strap~~	~~1.75~~	~~0.055~~
~~Lap belt tiedown strap~~	~~1.25~~	~~0.055~~
~~Side strap~~	~~1.75~~	~~0.055~~

3.4.11.7 Strap attachment methods.--

3.4.11.7.1 Stitch pattern and cord size.--Stitch pattern and cord size shall sustain a minimum of 100 pounds per inch of stitch length, and shall comply with Figure 7.

3.4.11.7.2 Wrap radius.--The wrap radius shall be the radius of the fitting over which the strap is wrapped at buckles and anchorages, as shown on Figure 8. The strap wrap radius shall be not less than 0.062-inch.

3.4.11.7.3 Hardware-to-strap folds--Figure 9 illustrates a recommended method to reduce the weight and size of attachment fittings by folding the strap at anchorage, or buckle fittings.

3.4.11.7.4 Surface roughness of fittings.--Fittings in contact with the straps shall have a maximum surface roughness of RMS-32 to prevent fraying of the strap due to frequent movement over the metal.

3.4.11.7.5 Belts, harnesses, and strap attachment.--Belts, harnesses, and straps shall be attached in a manner to preclude either improper alignment of the occupant or premature failure due to stress concentrations caused by misalignment of components during any possible seat deflection, body orientation, or a combination of both during the crash sequence. ~~Distance between the inner edges of the shoulder straps at the~~ 27 ~~seat back shall not exceed 2 inches.~~ Both shoulder straps shall be served by a single retractor.

3.4.11.7.6 Attachment-release buckle.--The restraint harness attachment-release buckle shall be of the quick-release 28 type and require intentional release by the occupant to activate the release mechanism. A positive locking device shall be incorporated in the attachment-release buckle to prevent unintentional release of any component of the restraint harness. This device shall give positive indication of any unlocked condition. The intentional release of the restraint harness shall be uncomplicated, and the buckle shall be capable of being operated with only one finger of either hand while tension equal to the occupant's weight is supported by the harness. The force required to release the harness with only one finger shall be not less than 15 pounds and not more than 25 pounds. The buckle shall be of a lift lever release configuration and shall eject lap belt and shoulder strap fittings simultaneously. 29 Hardware components shall carry the restraint harness design loads without permanent deformation. The positive locking mechanism of the attachment-release buckle shall be protected to prevent fouling of the mechanism by clothing or equipment worn by the seat occupant.

3.4.11.7.8 Inertia reel.--Shoulder strap inertia reel shall be provided which will store sufficient strap to permit full gun envelope coverage and tail rotor observation. The reel shall be located close to the shoulder strap guide point at the back of the seat to minimize strap elongation. The strength requirement shall be as shown in Table 1. The shoulder strap reel or guide at shoulder height (see Figure 6) shall be attached to rigid seat structure to prevent excessive de- 30 flection.

3.5 Dimensions.--Seats shall comply with the dimensions shown in Figure 14. Unless otherwise specified, a tolerance of ±1/16 inch will be allowed for seat overall dimensions. Restraint system webbing dimensions shall comply with Table ~~III~~ 1. (23)

3.6 Weight.--The completed seat system, including the restraint subsystem, all parts and adequate finish coating, shall not exceed the total weight tabulated below:

Seat Type	Weight (lbs)
I	28
II	50
III	100

(31)

3.7 Environment.--The seat system shall be designed to meet the requirements of paragraph 3.4 after exposure to the following environmental conditions:

3.7.1 Temperature.--The seat system shall withstand non-operating exposure as well as deliver specified performance when subjected to the high- and low-temperature tests in accordance with Methods 501 (Procedures I and II) and 502, respectively, of MIL-STD-810. The test temperature for Method 502 shall be as specified by the procuring activity (see 6.2).

3.7.2 Sunshine.--All materials used in the construction of any seat system component or assembly which may be subjected to prolonged exposure to sunshine shall show no evidence of any degrading effect when subjected to the sunshine test specified in Procedure I of Method 505 of MIL-STD-810.

3.7.3 Humidity.--The seat system shall operate satisfactorily during and after being subjected to the humidity test(s) specified in Method 507 of MIL-STD-810. The procedure to be used shall be specified by the procuring activity (see 6.2).

3.7.4 Fungus.--If any material utilized in the construction of the seat system is suspected to be a nutrient to fungi, the material shall show no deterioration when subjected to fungus tests in accordance with Method 508 of MIL-STD-810.

3.7.5 Salt Fog.--All materials used in the construction of the seat system shall be corrosion-resistant or processed to withstand the salt fog test of Method 509 of MIL-STD-810 when in the "as-installed" condition.

3.7.6 Dust.--The seat system shall be capable of satisfactory operation after exposure to the dust test specified in Method 510 of MIL-STD-810.

3.7.7 Vibration.--The seat system shall be capable of satisfactory operation after being subjected to the vibration tests of Method 514, Procedure I (Parts 1, 2, and 3) of MIL-STD-810.

3.7.8 Mechanical shock.--Components and equipment shall withstand normal shipping, handling, and installation without damage to required functional operation.

3.8 Maintainability.--The procuring activity will specify the acceptable level of maintainability for the seat system (See 6.2). The maintainability program to achieve, demonstrate, and assure retention of the seat system maintainability shall be in accordance with MIL-STD-471.

3.9 Reliability.--Because of the emergency nature of the seat system, prime importance shall be placed upon the attainment of a high overall degree of reliability. A reliability program shall be established in accordance with MIL-STD-785. The goal for the probability of success shall be as specified by the procuring activity (See 6.2). As a part of the reliability analysis, the contractor shall conduct a failure mode analysis for each seat system component and subsystem which could, by failing, adversely affect the crash survival of the occupant. This analysis shall provide (1) the probability of failure, (2) the expected mode(s) and cause(s) of failure, and (3) the consequence of each mode of failure.

3.10 Finish.--Aluminum-alloy parts shall be anodically treated in accordance with the MIL-A-8625, Type II, undyed, and noncorrosion resistant steel parts shall be cadmium plated in accordance with QQ-P-416 or zinc plated in accordance with QQ-Z-325.

3.11 Identification of product.--

3.11.1 Seat system.--A nameplate, permanently and legibly filled in with the following information, shall be secured to ~~the underside of the seat bottom, or the nomenclature may be stamped on the underside of~~ the seat ~~bottom~~ in a location capable of being read after the seat is installed. The information marked in the spaces provided on the nameplate shall be in accordance with MIL-STD-130.

Seat, Helicopter Gunner
Type (I or II as applicable)
Specification MIL-S-XXXX (AV)
Stock No. ____________________
Manufacturer's Part No.____________
Contract or Order No.______________
Weight________________
U.S. Property__________________

3.11.2 Restraint subsystem identification--Both the shoulder harness and the lap belt shall have a permanent nameplate (label) securely attached on a strap in a location for easy detection and installation. Each nameplate (label) shall contain the following information:

Nomenclature ____________________
Specification ____________________
Date of manufacture ____________________
Name of manufacturer ____________________
Federal stock number ____________________
Retirement date ____________________

3.11.3 Warning Placard.--A cloth placard, permanently and legibly filled in using ½ inch letters with the following statement, shall be securely sewn to the front of the seat back in a conspicuous location: (32)

W A R N I N G

DO NOT STOW

EQUIPMENT

UNDER SEAT

3.12 Workmanship.--The seat, including all parts and accessories, shall be constructed and finished in a thoroughly workmanlike manner. Particular attention shall be given to neatness and thoroughness of welding, riveting, machine-screw assemblies, painting, freedom of parts from burrs and sharp edges, unraveled edges of cloth, and straightness of stitched seams.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection.--Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.2 Classification of tests.--The inspection and testing of the seat systems shall be classified as follows: (1) preproduction and (2) quality conformance.

4.3 Preproduction testing.--

4.3.1 Test samples.--The contractor shall subject test samples of the seat system to the preproduction tests specified in 4.3.3. The number of preproduction samples to be tested by the contractor shall be as specified by the procuring activity (see 6.2).

4.3.2 Test sample for the procuring activity.--When specified (see 6.2), complete sample seat system(s) shall be submitted to the procuring activity. The number of sample seat systems shall be as specified by the procuring activity.

4.3.3 Preproduction tests.--The preproduction tests shall consist of all the tests specified under 4.5.

4.4 Quality conformance tests.--Quality conformance tests shall consist of the following: (1) individual and (2) sampling.

4.4.1 Individual.--Each seat system shall be subjected to the examination of product test specified in 4.5.1.

4.4.2 Sampling.--Seat systems shall be selected at random (see 4.4.2.1) by the authorized Government representative or inspector and subjected to the following tests:

(a) Interchangeability (see 4.5.2)
(b) Dynamic (see 4.5.3.2)
(c) Ballistic (see 4.5.3.3) (for Type II and Type III seats).

4.4.2.1 Test Quantities.--Seat systems in the quantities specified below shall be subjected to the sampling tests:

(a) Two seat systems from each lot of 200, or fraction thereof, of each type and class.
(b) Three seat systems from each lot of 500, or fraction thereof above 200, of each type and class.
(c) One seat system from each additional lot of 500, or fraction thereof above 500, of each type and class.

4.4.2.1.1 Lot.--A lot shall consist of seat systems manufactured under essentially the same conditions and submitted for acceptance at substantially the same time.

4.4.2.2 Rejection and retest.--Failure of any seat system to pass the sampling tests shall be cause for rejection of the entire representative lot. If, in the opinion of the inspector, such failure is attributable to faulty workmanship or other defects unlikely to occur throughout the lot,

subsequent tests may be made on three additional seat systems chosen at random from the suspected faulty lot. Failure of any one of these additional systems shall be cause for the final rejection of the entire lot represented.

4.4.2.3 Individual tests may continue--For production reasons, individual tests may be continued pending the investigation of a sampling test failure. But final acceptance of the entire lot or lots produced later shall not be made until it is determined that all items meet all the requirements of the specification.

4.4.3 Defects in items already accepted.--The investigation of a test failure could indicate that defects may exist in items already accepted. If so, the contractor shall fully advise the procuring activity of all the defects liable to be found and the method of correcting them.

4.5 Test methods.--

4.5.1 Examination of product.--Each seat system shall be carefully examined to determine conformance with this specification and the manufacturer's drawings with respect to materials, workmanship, design, standard parts, weight, finish, adjustments, dimensions, and markings. Special attention shall be given to the energy absorption mechanism.

4.5.2 Interchangeability.--Conformance to the requirements for interchangeability of component parts shall be determined by means of suitable jigs and sample parts.

4.5.3 Performance tests.--The seat system shall be tested as a complete unit and shall be mounted in a suitable jig or fixture by using the normal seat system to aircraft structure tie-down provisions. It shall then be subjected to, and withstand, without failure, the applicable loads specified in 4.5.3.1 and 4.5.3.2. All static tests shall be conducted under simultaneous conditions of floor buckling and warping, as shown on Figure 10. The seat system shall be loaded to either a plus or minus angle for the floor buckling, whichever is more critical, as determined by the procuring activity. Subsequently, the seat shall be subjected to, and pass, the ballistic test of 4.5.3.3.

4.5.3.1 Static tests.--The occupant restraint subsystem shall be tested with the rest of the seat system during the static tests specified below. In addition, the lap belt and shoulder harness shall be statically tested separately to determine compliance with Table 1, thereby insuring that all components possess the required strength and elongation.

4.5.3.1.1 Unidirectional loads.--Where separate strength and deformation requirements have been specified in Table 3 for longitudinal, vertical, and lateral loading of seat systems, the seat system shall be tested under these loads applied separately.

4.5.3.1.2 Combined loads.--The seat system shall not lose structural integrity under conditions of combined loads as specified in Table 3.

4.5.3.1.3 Static load application method.--The static test loads shall be applied as shown on Figure ~~7~~ 11 through a body block which is contoured to approximate the torso of the 95th percentile occupant (see 6.3.1) in the seated position. The body block shall include representations of the neck, the shoulders, and the upper legs. The buttock contours over the ischial tuberosities of a seated occupant shall be simulated as shown on Figure ~~7~~ 11. The loads calculated by multiplying 33
the weight of the occupant and equipment plus the weight of the seat by the required load factor (G) shall be applied in increments of 275 pounds, plus or minus 25 pounds, while the load-deformation performance of the seat is recorded (see 4.5.3.1.5). That portion of the static loading that must be withstood by the occupant restraint subsystem shall be applied to the static test loading body block (Fig ~~7~~ 11) and the remainder of the load representing inertial loading of other seat components shall be applied separately to the appropriate structure.

4.5.3.1.4 Load determination.--Total static test load to be applied, for all directions other than downward, shall be determined by multiplying the required design load factor (G) specified in Table 3 by the sum of the 95th percentile clothed occupant weight (see 6.3.2) plus the weight of the seat. In the case of downward loads, the required G load from Table 3 shall be multiplied by the sum of the weight of that portion of the seat system which moves vertically during the stroking of the energy absorption mechanism plus the effective weight of the 50th percentile clothed occupant (see ~~6.3.10.~~ 6.3.2). 14

4.5.3.1.5 Deflection measurements.--Deflection shall be measured from the seat pan (see Figures 1 and 2).

4.5.3.2 Dynamic tests.--Dynamic preproduction tests of the seat system shall be conducted to the conditions specified in Table 4 and the seat system shall evidence no loss of structural integrity. Dynamic sampling tests of the seat systems shall be conducted in accordance with Test 1 specified in Table 4 and the seat system shall evidence no loss of structural integrity. The energy absorption mechanism(s) (see 3.4.8) in both preproduction and sampling dynamic tests shall limit the acceleration measured on the seat pan to a value which insures that future 5th through 95th percentile

clothed seat system occupants will not experience vertical accelerations in excess of human tolerance (see 6.3.9) during crash pulses up to and including the 95th percentile potentially survivable accident pulse (see 6.3.5). A 95th percentile clothed anthropomorphic dummy occupant (see 6.3.2) shall be used to simulate each seat system occupant for these tests.

4.5.3.3 Ballistic Tests.--(To be supplied)

4.5.4 Environmental tests.--At least one test sample shall be subjected to each of the following environmental tests in the order listed.

4.5.4.1 High temperature.--High-temperature tests shall be conducted in accordance with Method 501, Procedures 1 and II of MIL-STD-810.

4.5.4.2 Low temperature.--Low-temperature tests shall be conducted in accordance with Method 502 of MIL-STD-810. The test temperature shall be as specified by the procuring activity (see 6.2).

4.5.4.3 Humidity.--Humidity tests shall be conducted in accordance with Method 507 of MIL-STD-810. The procedure to be employed shall be as specified by the procuring activity (see 6.2).

4.5.4.4 Fungus.--If any material utilized in the construction of the seat system is suspected to be a nutrient to fungi, the material shall be tested in accordance with Method 508 of MIL-STD-810.

4.5.4.5 Salt fog.--Salt fog tests shall be conducted in accordance with Method 509 of MIL-STD-810 with the seat system in the "as-installed" condition.

4.5.4.6 Dust.--The seat system shall be subjected to the dust test specified in Method 510 of MIL-STD-810.

4.5.4.7 Vibration.--Vibration tests shall be conducted in accordance with Method 514, Procedure I (Parts 1, 2, and 3) of MIL-STD-810.

4.5.4.8 Maintainability.--The maintainability program to demonstrate and assure retention of seat system maintainability shall be in accordance with MIL-STD-471.

4.5.5 Human Engineering Mock-up.--A human engineering mock-up of each new gunner seat system concept shall be fabricated and demonstrated. The seat mock-up shall include a complete and operable restraint system and the seats rotational and locking features shall be capable of being demonstrated. 34

Occupants representing 5th and 95th percentile gunners with and without survival vests and troops with and without combat assault equipment shall be used to demonstrate restraint system use, seat accommodations, and lack of encumbrances during ingress, egress and gunnery operations. Occupants shall wear warm weather, intermediate weather, and cold weather clothing for each of the demonstrations. Medium rucksacks and butt packs with combat assault loads shall be worn by the troops and the SRO-21 survival vest shall be worn by the gunners. A report shall be prepared documenting ingress, hookup and egress times for each combination of clothing, equipment and personnel percentile. Problems encountered shall be documented and solutions presented. (34)

4.6 Inspection of preparation for delivery.--Packaging and marking shall be inspected to determine compliance with section 5 of this specification.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging.--Preservation and packaging shall be level A or C, as specified (see 6.2).

5.1.1 Level A.--Each seat shall be preserved and packaged in accordance with MIL-P-116, Method III, in a weather resistant unit container conforming to PPP-B-636.

5.1.2 Level C.--Each seat shall be preserved and packaged in a manner that will afford adequate protection against corrosion. deterioration and physical damage during shipment from supply source to the first receiving activity for immediate use. This level may conform to the supplier's commercial practice, provided the latter meets the requirements of this level.

5.2 Packing.--Packing shall be level A, B or C, as specified (see 6.2).

5.2.1 Level A.--Seats preserved and packaged as specified in 5.1.1 shall be packed in overseas type shipping containers conforming to PP-B-601 or PPP-B-621. As far as practicable, shipping containers shall be of uniform shape and size, or minimum cube and tare consistent with the protection required, and contain identical quantities. The gross weight of each shipping container shall not exceed the weight limitation of the specification. Containers shall be closed and strapped in accordance with the specification and appendix thereto.

5.2.2 Level B.--Seats preserved and packaged as specified in 5.1.1 shall not be overboxed for domestic shipments. The unit container, closed and strapped in accordance with the applicable appendix of the container specification, shall be the shipping container.

5.2.3 Level C.--Seats shall be packed in a manner that will afford adequate protection at the lowest rate against damage during direct domestic shipment from the supply source to the first receiving activity for immediate use. This level shall conform to applicable carrier rules and regulations and may be the supplier's commercial practice, provided the latter meets the requirements of this level.

5.3 Physical protection.--Cushioning, blocking and bracing shall be in accordance with MIL-STD-1186, except that for domestic shipments, water-proofing requirements for cushioning materials and containers shall be waived when preservation, packaging and packing of the item are for immediate use or when drop tests of MIL-P-116 are applicable.

5.4 Marking.--Interior packages and exterior shipping containers shall be marked in accordance with MIL-STD-129.

6. NOTES

6.1 Intended use.--The seats covered by this specification are intended primarily for use by gunners in utility- and cargo-type helicopters. To ensure the long-term success of the seat system in achieving its purpose, the designers of the system and its components, subassemblies, and subsystems must consider throughout the design and development phases the ease or difficulty with which required maintenance tasks may be accomplished. Degradation of system performance may result over a long period if maintenance access is extremely restricted, numerous special tools are required, frequent system/component maintenance is required, and/or maintenance instructions are inadequate. Seat system useful life should be equal to, or greater than, the expected life of the aircraft in which the seats are to be installed.

6.2 Ordering data.--Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Type of seat required (see 1.2).
(c) If preproduction inspection and testing are required (see 3.2):
    (1) The number of preproduction test samples required (see 4.3.1); and
    (2) Whether sample seat systems shall be submitted to the procuring activity (see 4.3.2 and 4.5.4).
(d) Requirement for test temperature (see 3.7.1 and 4.7.4.2).
(e) Procedure for humidity test (see 3.7.3 and 4.5.4.3).

(f) Acceptable level of maintainability for the seat system (see 3.8).
(g) The goal for the probability of seat system success (see 3.9).
(h) Seat dimensions (see 3.5).
(i) Whether seat cushions are required (see 3.4.10).
(j) Any special painting requirements (see 3.10).
(k) Levels of preservation, packaging and packing required (see 5.1, and 5.2).
(l) Whether special marking for shipment is required (see 5.4).
(m) Where the preproduction test sample should be sent, the activity responsible for testing, and instructions concerning the submittal of the test reports (see 4.3.2).

6.3 Definitions.--For the purpose of this specification, the following definitions apply.

6.3.1 Anthropometric data.--USANLABS TR 72-51-CE shall be referred to as a source document for anthropometric data on personnel.

6.3.2 95th percentile clothed occupant.--Unless otherwise specified by the procuring activity, the 95th and 50th (14)
percentile clothed occupant is defined as the 95th and 50th percentile occupant, in accordance with USANLABS TR 72-51-CE wearing the following items:

	~~Weight (lbs)~~	
~~Soldier~~	~~202.0~~	(35)
~~Clothing~~	~~3.2~~	
~~Boots~~	~~4.0~~	
~~Isvesta*~~	~~32~~	
~~Helmet~~	~~3.0~~	
~~TOTAL WEIGHT~~	~~243.3~~	

~~*Isvesta - Individual Survival Vest for Aircrew Members~~

Item	Weight (lbs)	
Flying Helmet SPH-4	3.3	(35)
Nomex Flying Suit (2 pcs)	3.0	
Standard Underwear and Socks	.1	

Item	Weight (lbs)
Combat Boots (size 12)	4.1
Nomex/Leather Flying Gloves ISVESTA (Individual Survival Vest For Aircrewmen)	.3
Carrier, Nomex	1.1
Std A Front Armor Plate w/Spall Shield (large)	16.0
Std A Rear Armor Plate w/Spall Shield (large)	19.0
Survival Components	8.0
Personal Weapon/Holster, Pistol, Belt	4.0
Life Preserver LPU-10P	3.0
TOTAL	62.0

6.3.3 Effective weight of occupant.--The effective weight of a seated occupant in the vertical direction is the sum of the following quantities: 80 percent of the occupant's body weight, 80 percent of the weight of the occupant's clothing less boots, and 100 percent of the weight of any equipment carried totally on the occupant's body above knee level.

6.3.4 G.--The term G is the ratio of a particular acceleration to the acceleration due to gravitational attraction at sea level; therefore, 10G represents an acceleration of 321.7 feet/second/second.

6.3.5 95th percentile potentially survivable accident.--Table 5 specifies the period (T), the peak G values, and velocity change (ΔV) for the triangular pulse shape illustrated on Figure 12. The pulses described by the values given in Table 5 are design pulses representative of the crash pulses occurring at the aircraft floor line in 95 percent of the potentially survivable rotary-wing Army aircraft accidents. The pulse parameters peak G, T, and ΔV are obtained from USAAMRDL Technical Report 71-22, entitled "Crash Survival Design Guide."

TABLE 5.--DESIGN PULSES CORRESPONDING TO THE 95th PERCENTILE POTENTIALLY SURVIVABLE HELICOPTER ACCIDENT.

Impact direction (with respect to aircraft axis)	Velocity change Δ V (fps)	Peak G (G)	Pulse duration T (sec)
Longitudinal (Roll)	50	24	0.130
Vertical (Yaw)	42	48	0.054
Lateral (Pitch)	30	18	0.104

6.3.6 Occupant submarining.--In a crash with high vertical and longitudinal forces (measured along the seat longitudinal axis) present, the restrained body will tend to sink down into the seat first and then almost simultaneously be forced forward. If the seat system is provided with an improperly designed restraint system or seat cushion, the inertia load of the hips and thighs will pull the lower torso under the lap belt during the crash sequence. This phenomenon is referred to as occupant submarining.

6.3.7 Dynamic overshoot.--Dynamic overshoot exists when the seat occupant receives an amplification of the accelerative force applied to the seat. A loose or highly elastic restraint system, or a cushion with a high rebound potential which permits "bottoming out" on the seat pan, can facilitate dynamic overshoot.

6.3.8 Load-limiting device.--A load-limiting device is a device which limits the load in a structure to a preselected value.

6.3.9 Human tolerance to vertical accelerations.--For all vertical crash pulses up to and including the 95th percentile potentially survivable accident pulse (see 6.3.5), the 5th through 95th percentile clothed occupants (see 6.3.1) shall not experience accelerations with plateaus lasting longer and/or greater in magnitude than the values represented by the maximum acceptable acceleration duration-magnitude curve illustrated on Figure 13.

~~6.3.10 50th percentile clothed occupant weight.--Unless otherwise specified by the procuring activity, the 50th percentile clothed occupant effective weight is defined as 170 pounds.~~ 14

Custodian:

Army

Review Activities:

User Activities:

Preparing Activity:

Army -- Eustis Directorate
USAAMRDL

TABLE 3. SEAT DESIGN AND STATIC TEST REQUIREMENTS

Test Ref. No.	Loading Direction With Respect to Fuselage Floor	Load Required	Deformation Requirements[a]
1	Forward	See Figure 1	See Figure 1
2	Aftward	12G Minimum	No Requirement
3	Lateral[b]	See Figure 2	See Figure 2
4	Downward	14.5 G[d]	See Paragraph 3.4.7.3.1
5	Upward	8G Minimum	No Requirement
6	Forward[c,e,f]	See Figure 1	See Figure 1
Com-	Downward		
bined	Lateral[e]	9G Minimum	No Requirements

a The aircraft floor or sidewall shall be deformed in the xz and yz planes, as detailed in Figure 10, simultaneously with the "G" loads specified.

b The lateral loads shall be applied in the direction which is most critical. In the case of symmetrical seats, the loading direction is optional.

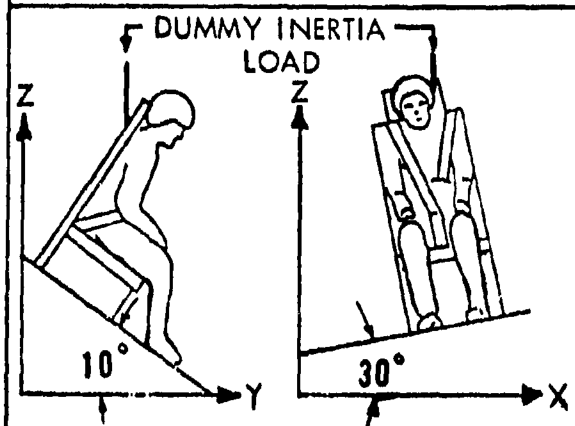
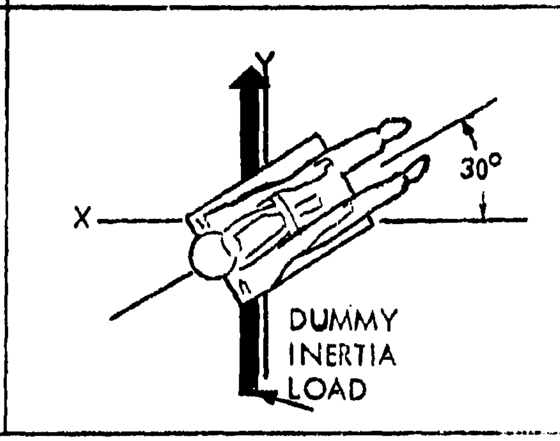
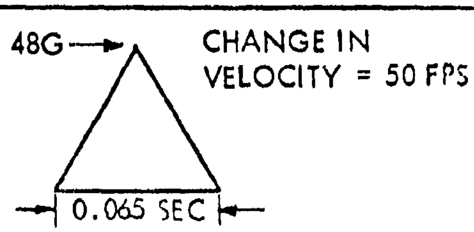
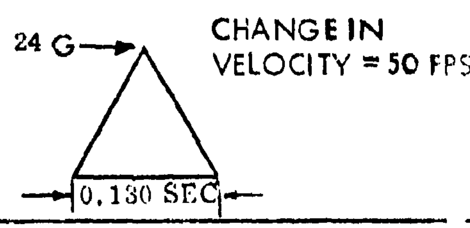
c In the event that no load-limiting device is used in the forward direction, a 20G load shall be used for this combined loading.

d If more than one load-limiter setting is provided, each should be tested.

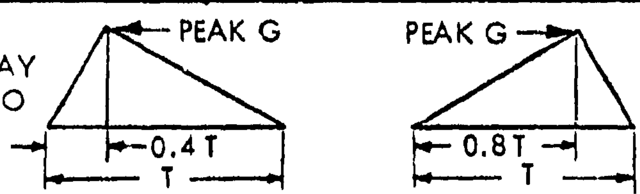
e The forward and lateral loads should be applied prior to the downward load application/ on seats which have vertical guides which could distort and impede vertical travel. (35)

f Resultant load of combined load condition shall not exceed vertical attenuator stroking load for seats where the vertical attenuator would stroke before reaching a higher resultant load. (37)

TABLE 4. DYNAMIC TEST REQUIREMENTS

TEST CONDITIONS AND SEAT ORIENTATION	
TEST 1: DOWNWARD, FORWARD, AND LATERAL LOADS	TEST 2: FORWARD AND LATERAL LOADS
	
TEST PULSE REQUIRED*	
	

* THE RISE TIME FOR THE TRIANGULAR PULSES MAY VARY BETWEEN THE TWO VALUES ILLUSTRATED (T = TIME):



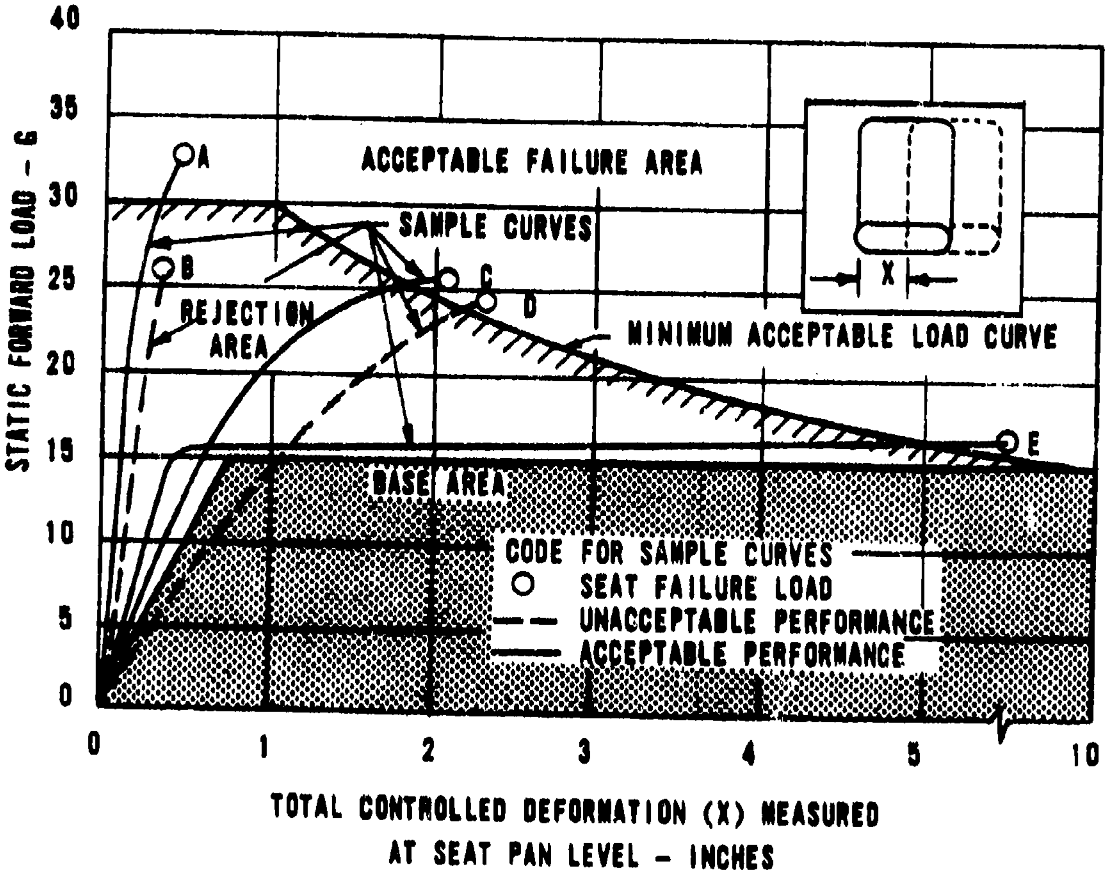


FIGURE 1. SEAT LOAD AND DEFLECTION REQUIREMENTS FOR LOADING MEASURED ALONG AIRCRAFT ROLL AXIS

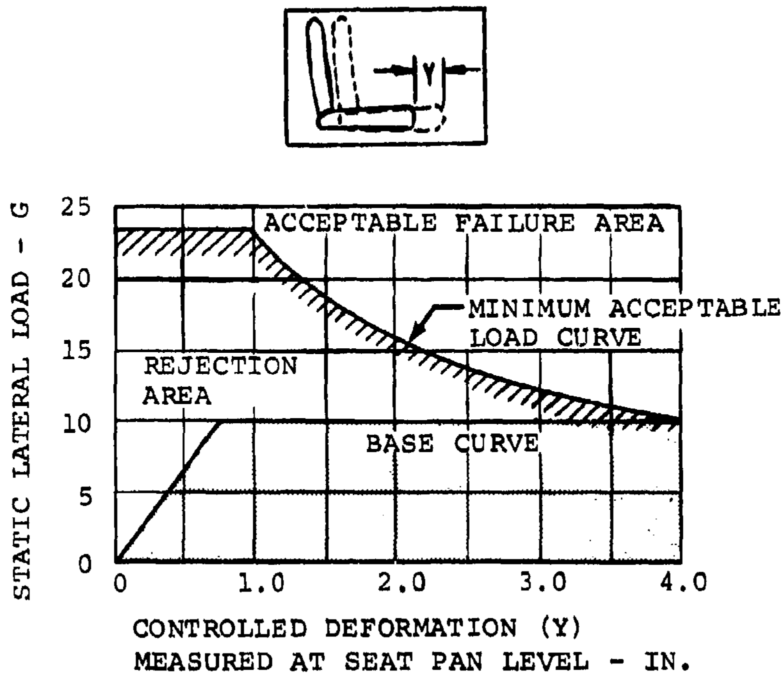


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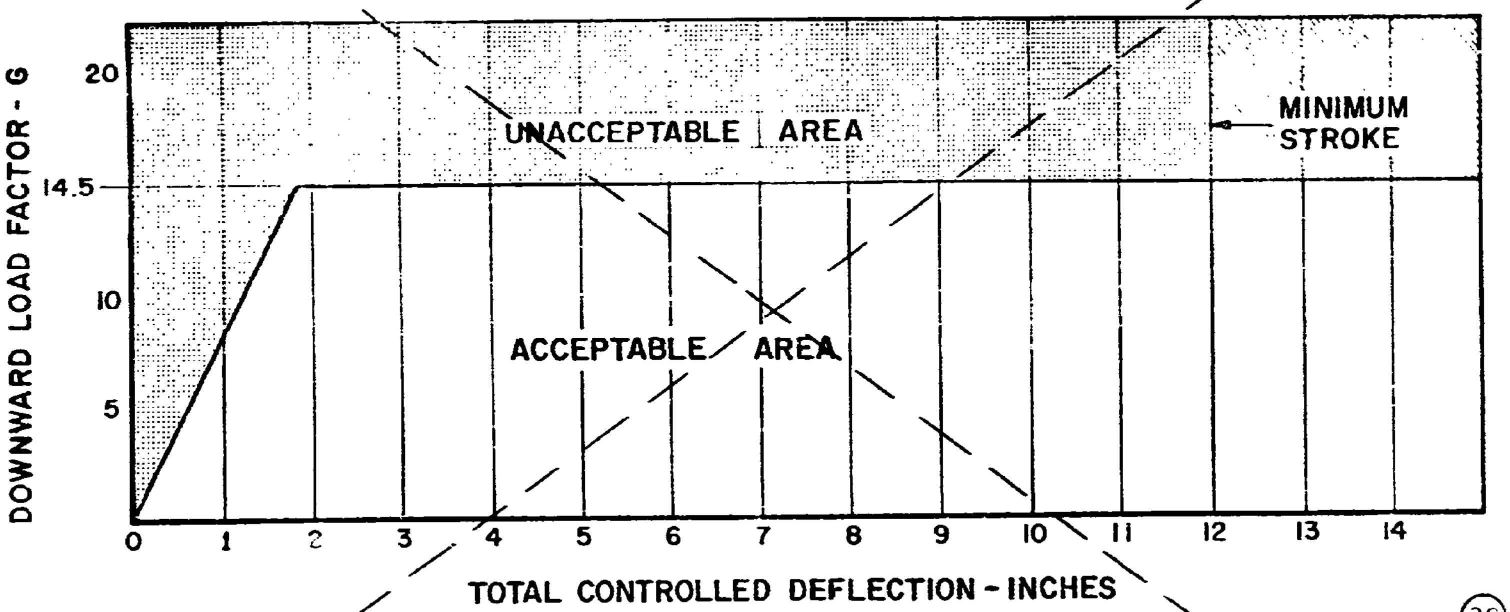
Figure 2. Seat Load and Deformation Requirements for Loading Measured Along Aircraft Pitch Axis.



~~Figure 3. Seat Downward Load and Deflection Requirements.~~

(39)

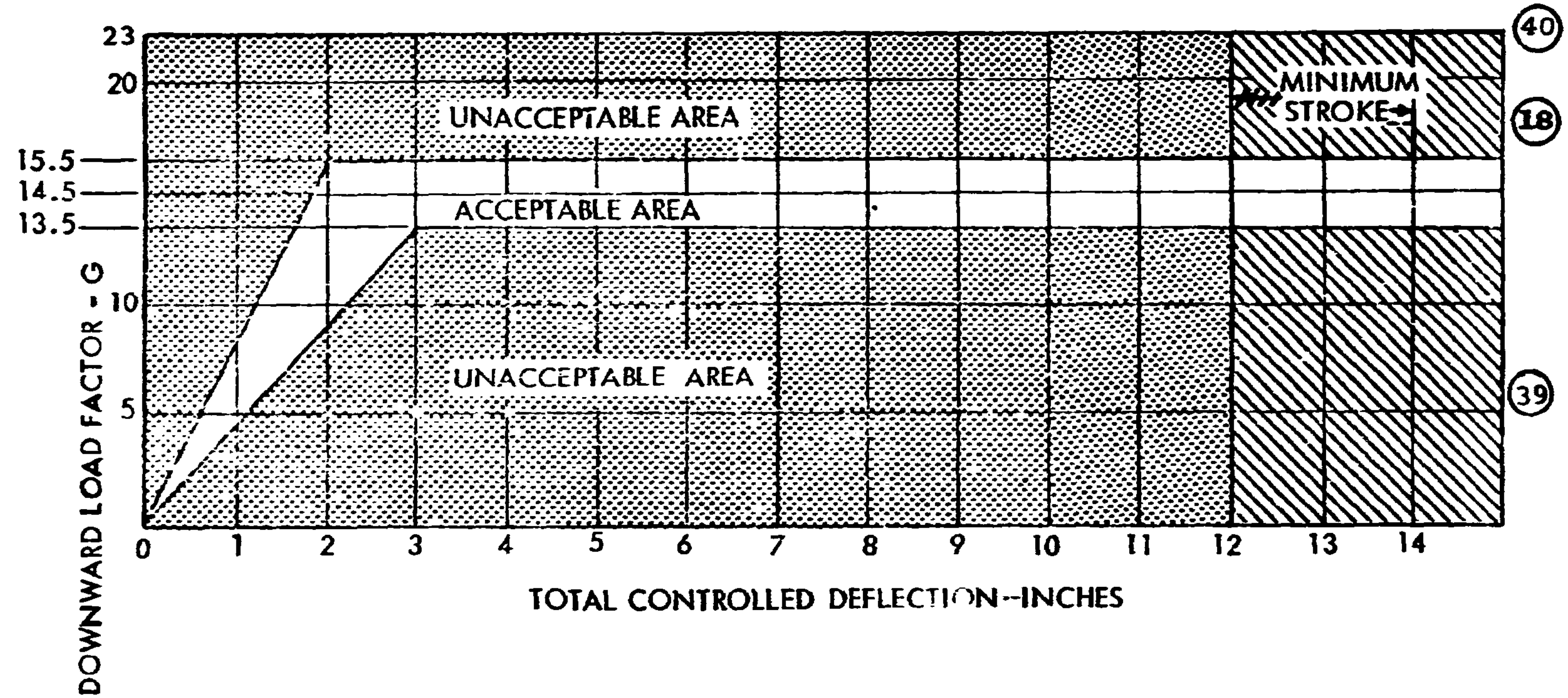
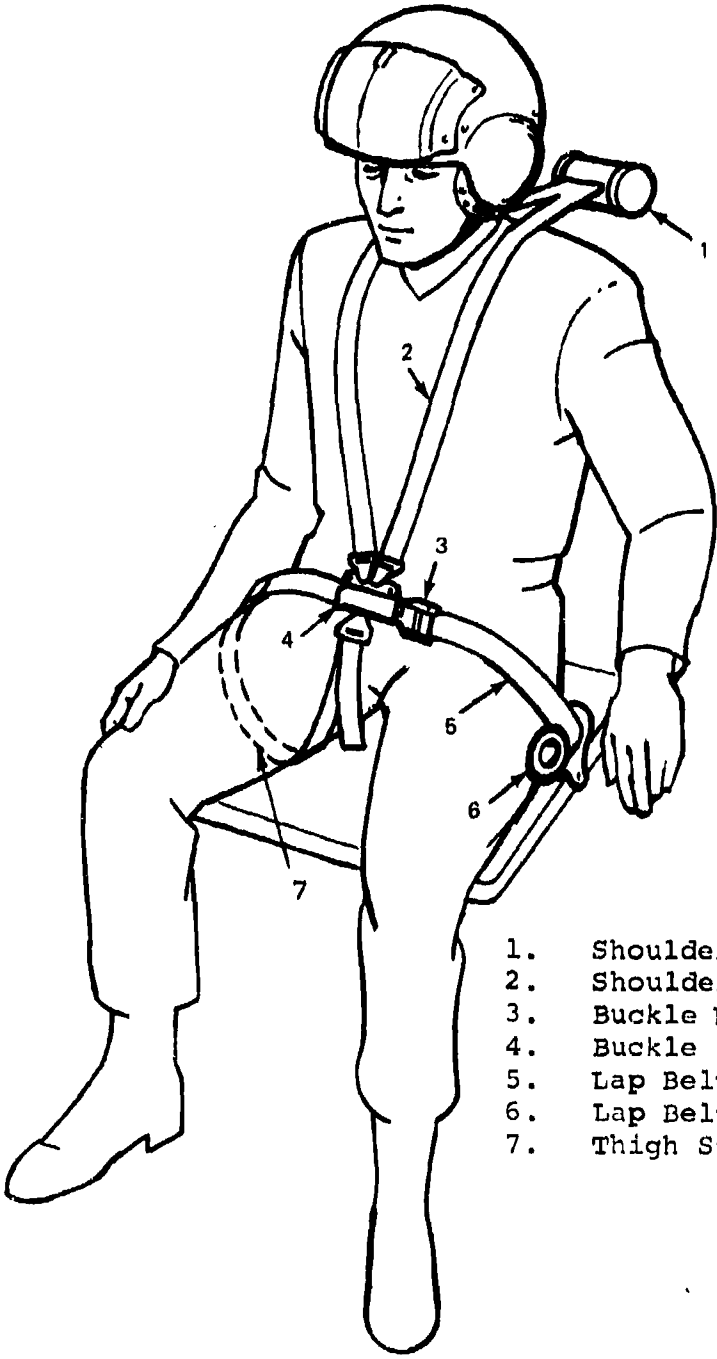


Figure 3. Seat Downward Load and Deflection Requirements for 50th Percentile.



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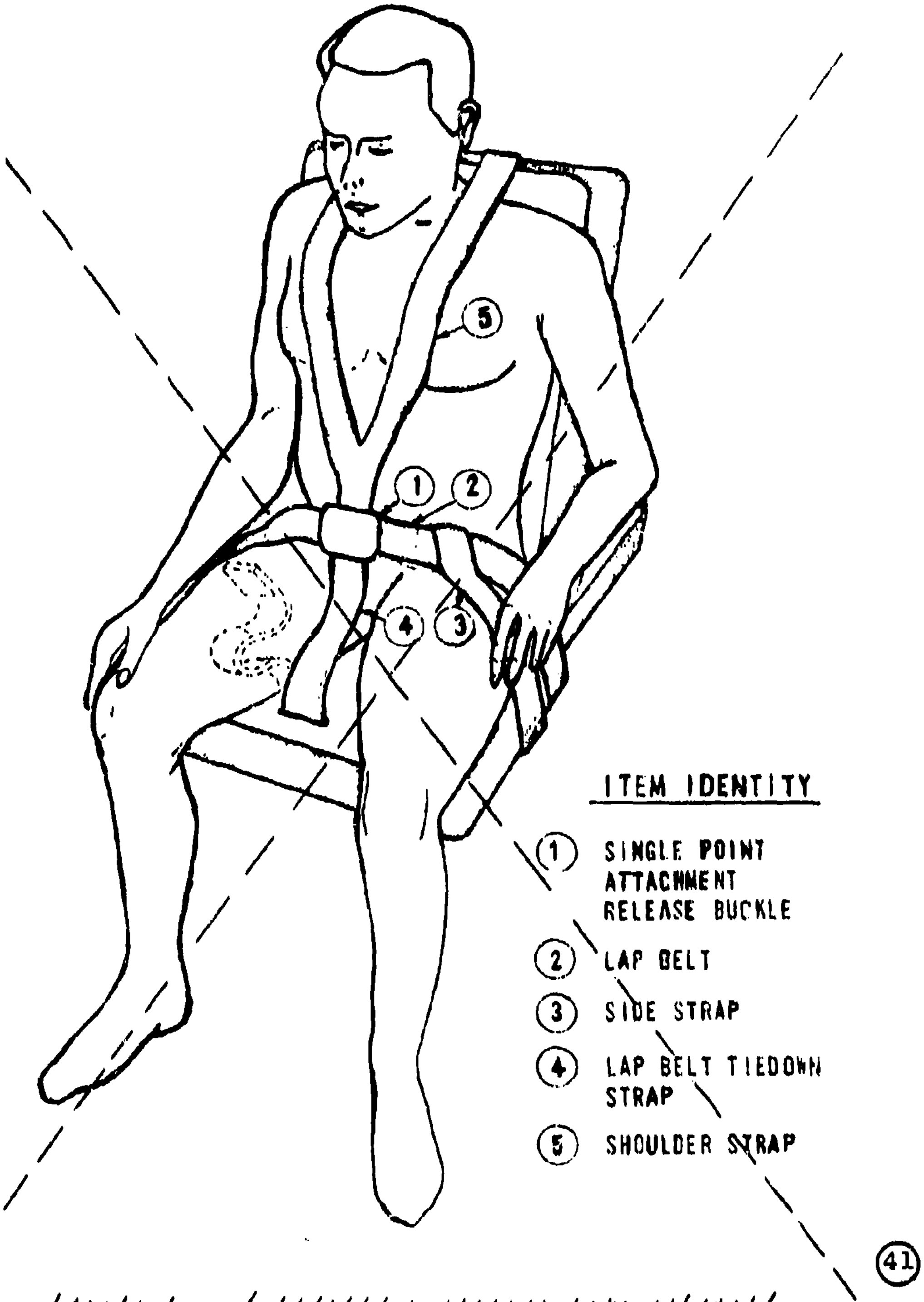
1. Shoulder Strap Reel
2. Shoulder Strap
3. Buckle Link
4. Buckle
5. Lap Belt
6. Lap Belt Reel
7. Thigh Strap

Figure 4. Restraint Subsystem Configuration.



~~FIGURE 4. RESTRAINT SUBSYSTEM CONFIGURATION~~

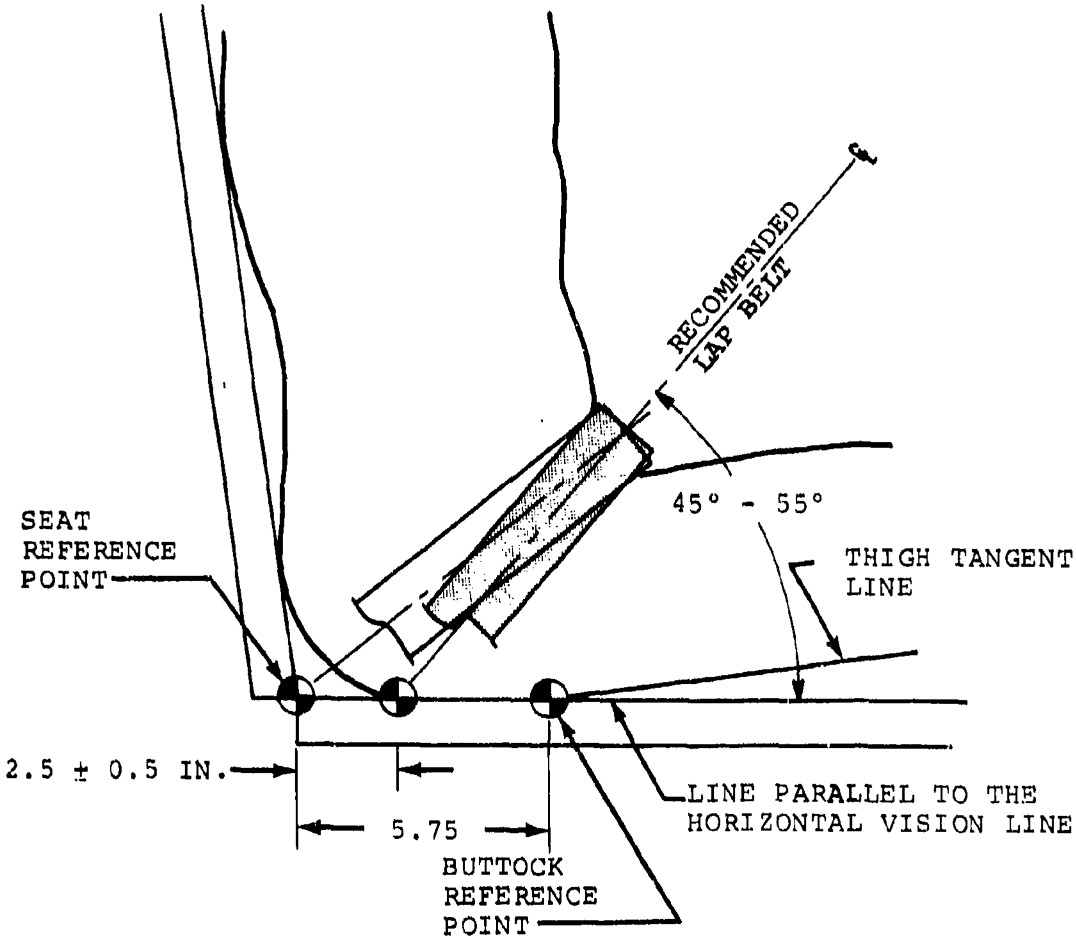


Figure 5. Lap-Belt Anchorage Geometry.

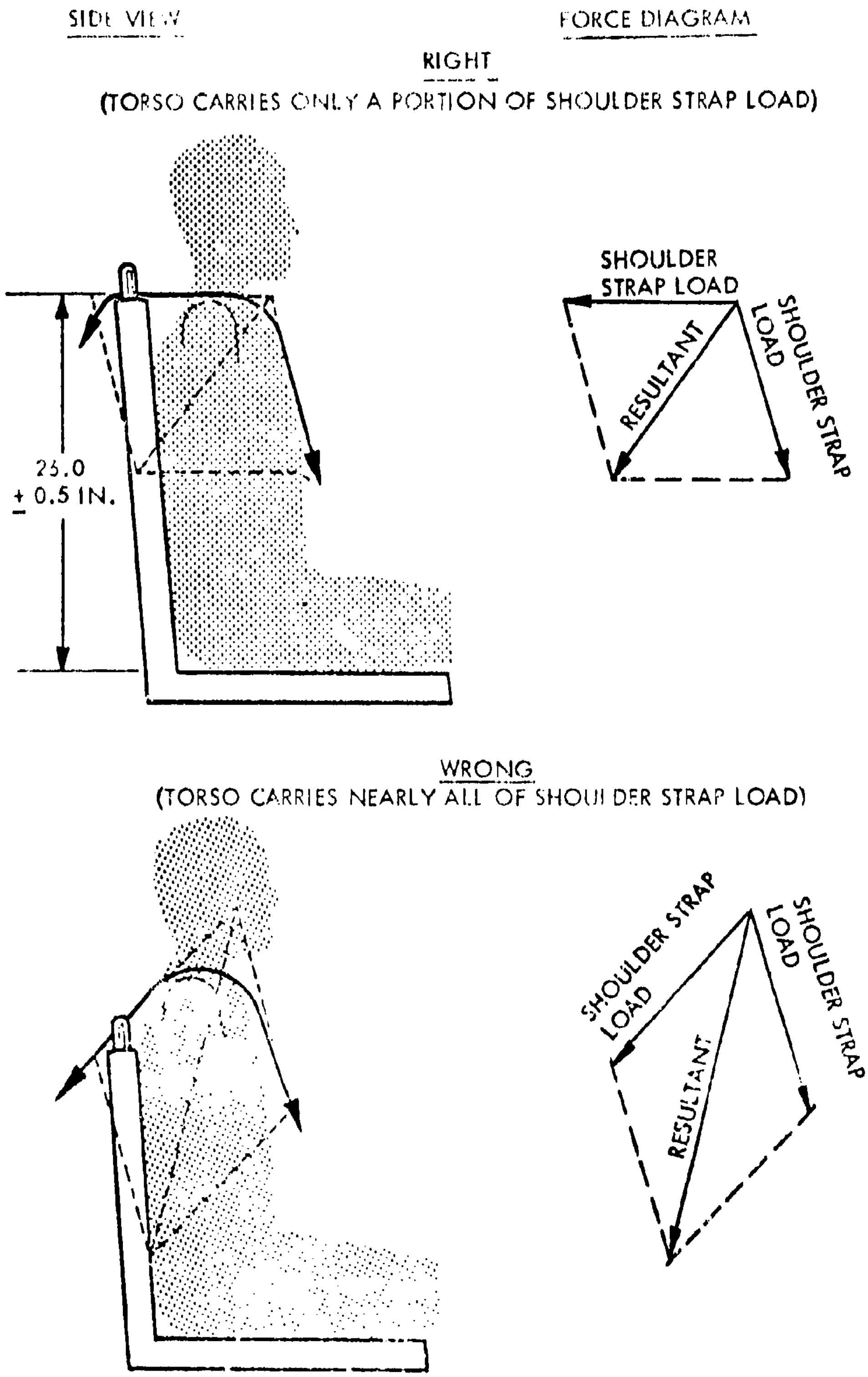


Figure 6. Shoulder Harness Anchorage Geometry.

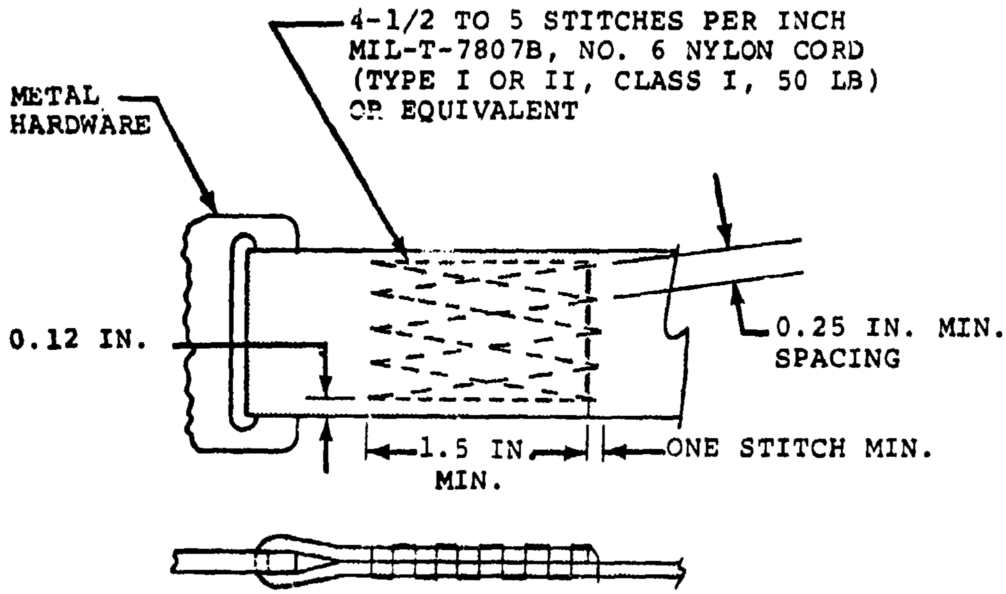


Figure 7. Stitch Pattern and Cord Size.

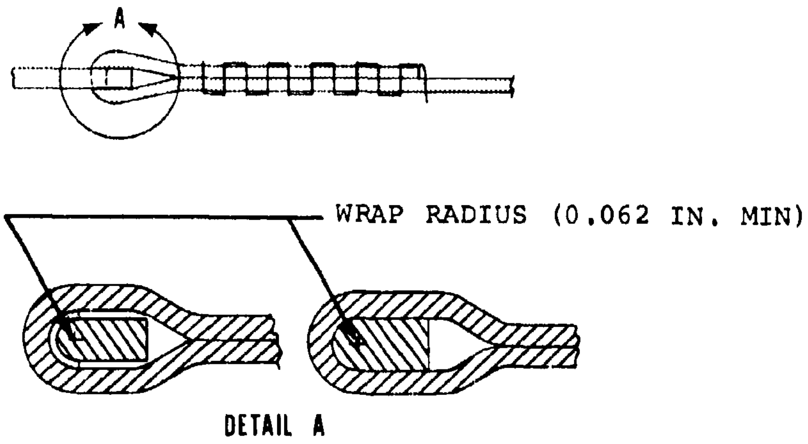


Figure 4-3. Wrap Radius for Webbing Joints.

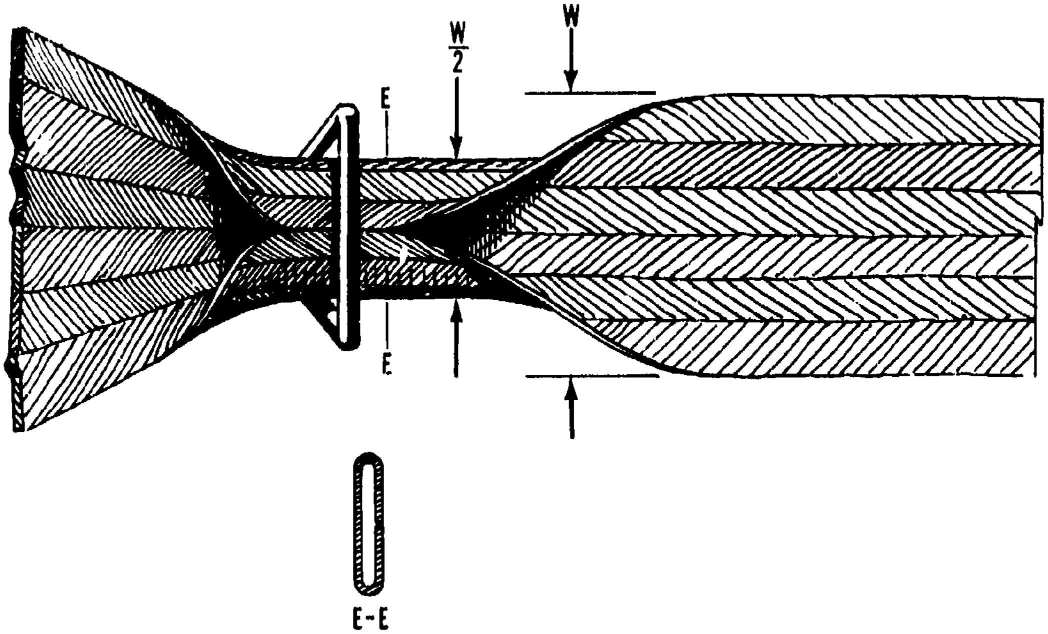


Figure 9. Webbing Fold at Metal Hardware Attachment.

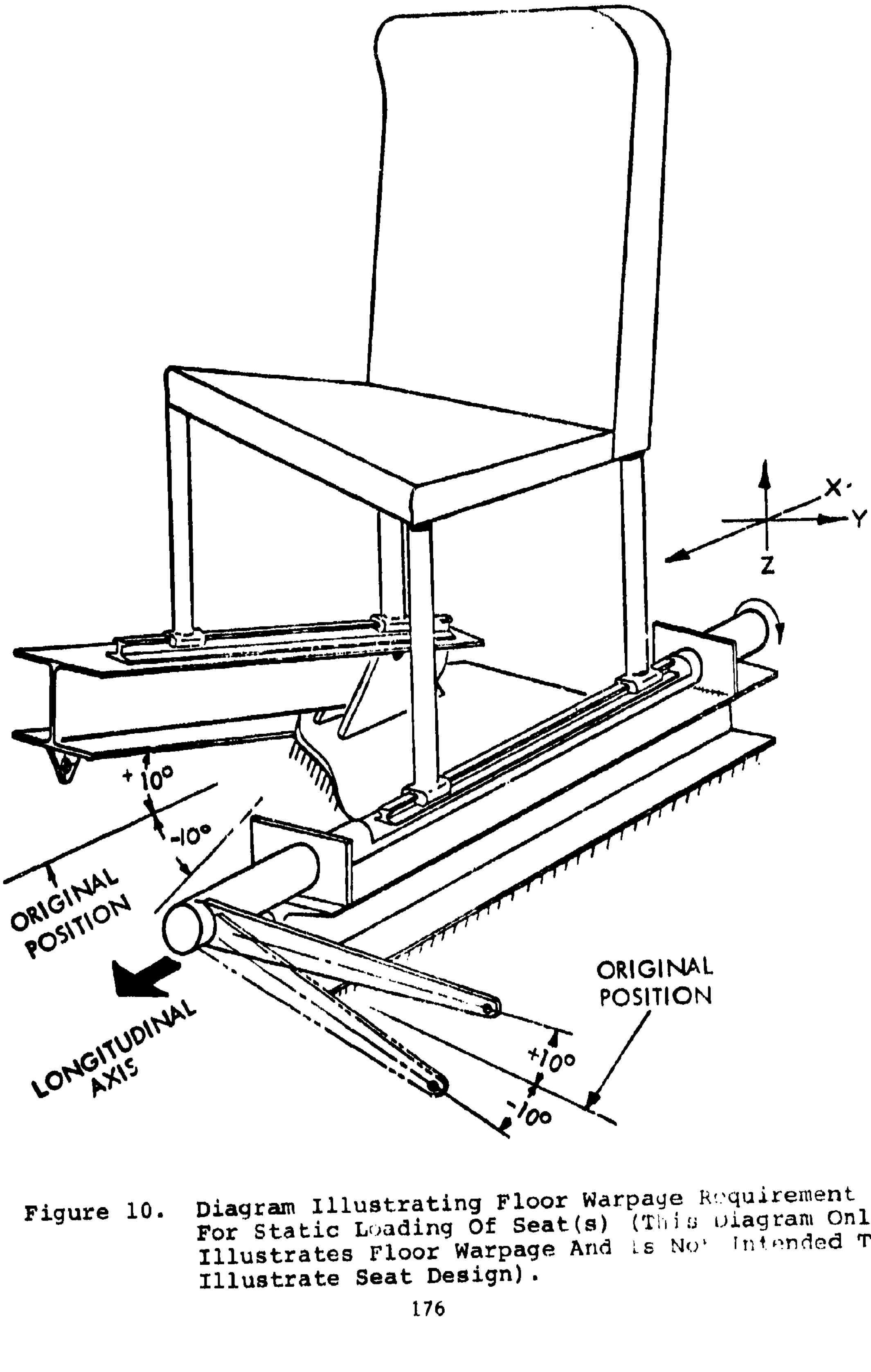


Figure 10. Diagram Illustrating Floor Warpage Requirement For Static Loading Of Seat(s) (This Diagram Only Illustrates Floor Warpage And Is Not Intended To Illustrate Seat Design).

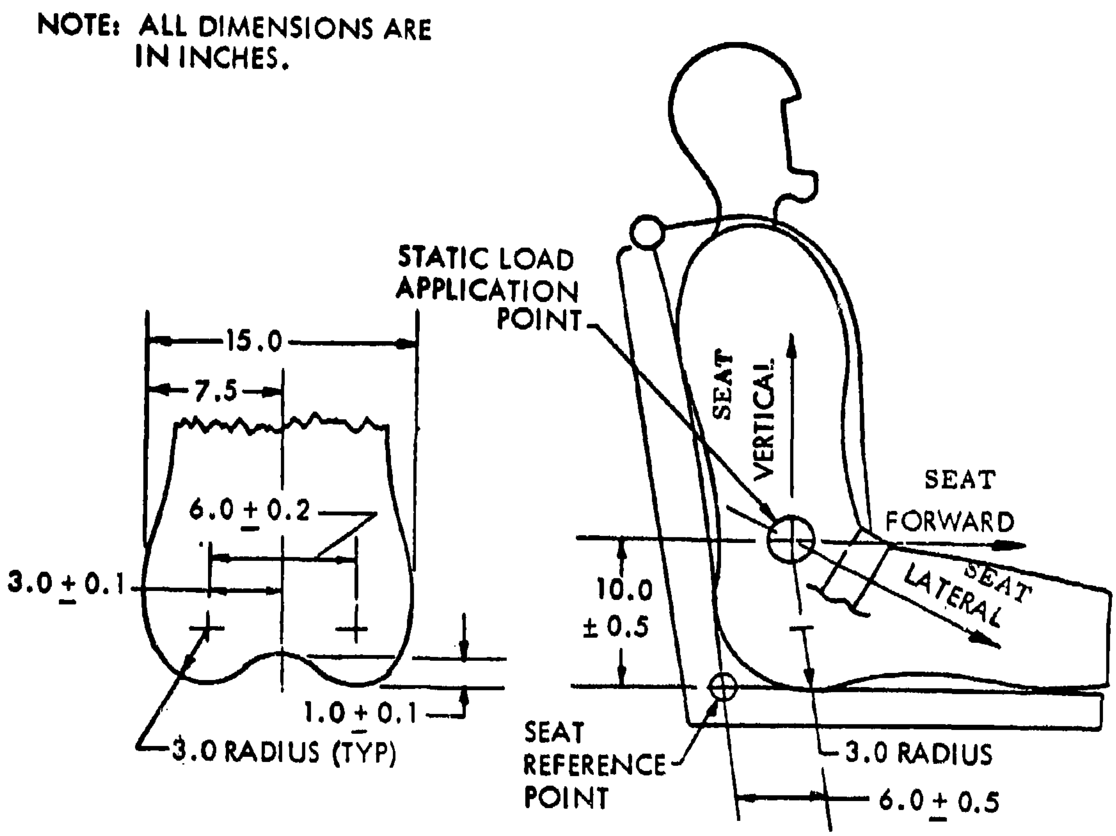


Figure 11. Static Load Application Point and Critical Dummy Pelvis Geometry.

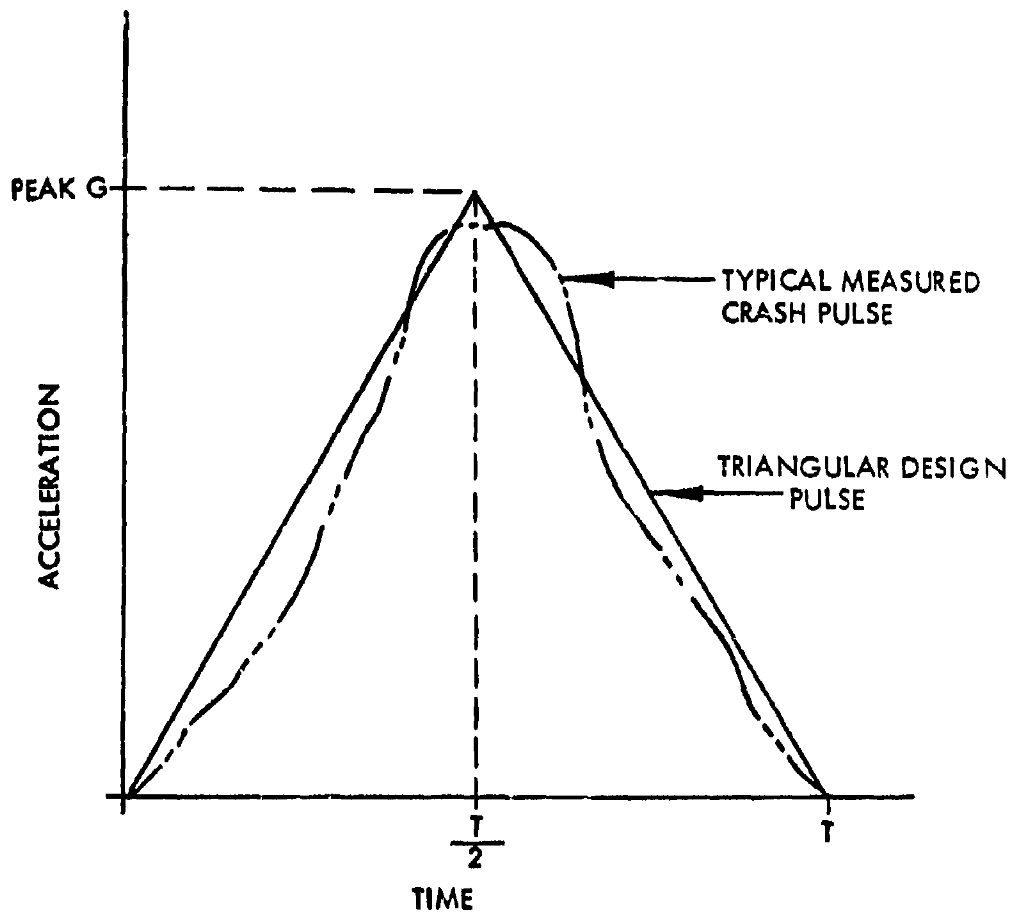


Figure 12. Typical Impact Pulse.

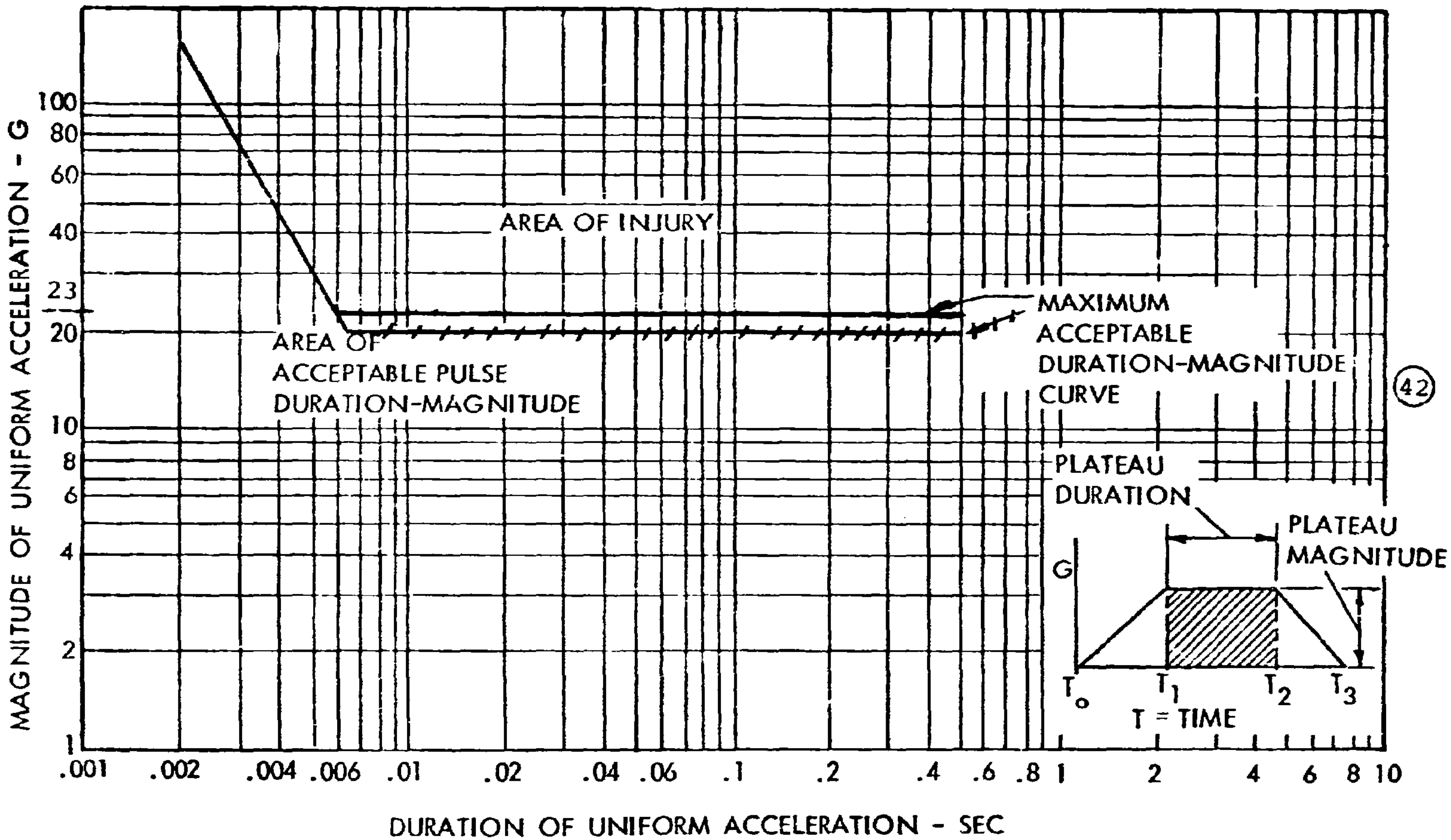
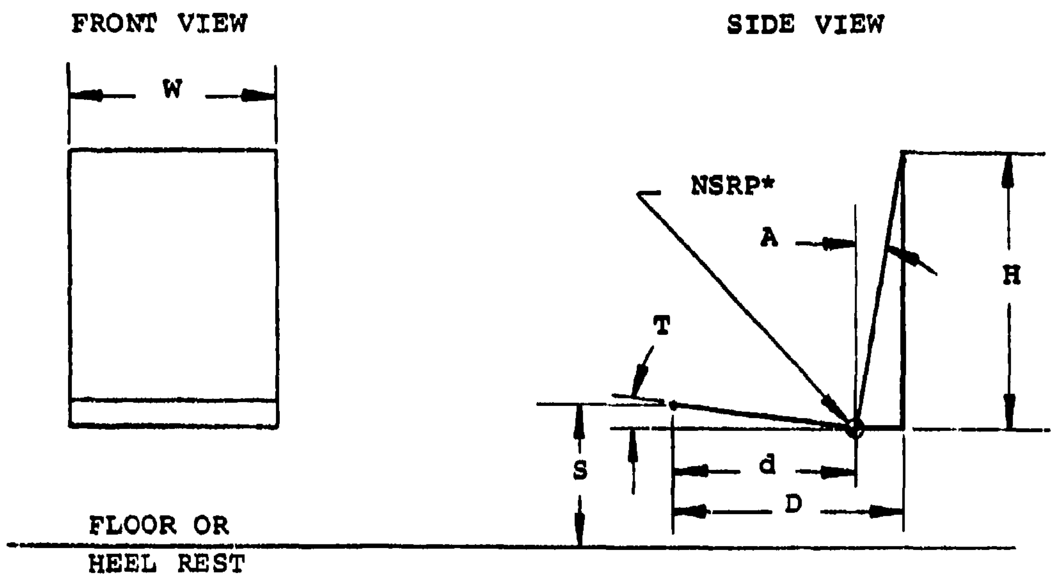


Figure 13. Maximum Acceptable Vertical Pulse Acceleration and Duration Values.



DIMENSIONS		MAXIMUM	MINIMUM
T	(DEGREES)	20	5
A	(DEGREES)	15	0
H	(INCHES)	38	25
W	(INCHES)	23	18**
D	(INCHES)	23	15
S	(INCHES)	18	17
d	(INCHES)	18	14

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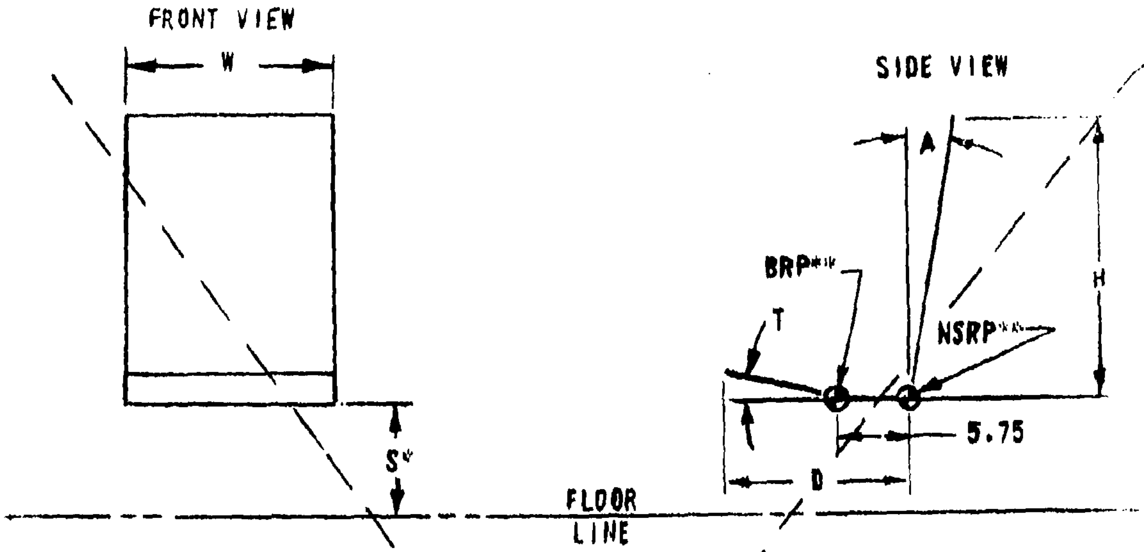
NOTES

* NSRP is the neutral seat reference point
** Seats with sides must have a minimum inside width of 20 inches

Figure 14. Seat dimensional limits (This figure presents max-min dimensional restrictions and is not intended to represent design).



DIMENSION		MAXIMUM	MINIMUM
T	(DEGREES)	20	5
A	(DEGREES)	15	10
H	(INCHES)	38	25
W	(INCHES)	23	20
D	(INCHES)	18	18
S*	(INCHES)	15	12

NOTES

* MAX-MIN S DIMENSIONS ARE EXCLUSIVE OF THE THICKNESS OF THE SEAT PAN THIS MUST BE ADDED TO THE MAX-MIN S DIMENSION IN THE ABOVE TABLE TO GET THE TRUE DIMENSION FROM THE NSRP TO THE FLOOR LINE

** NSRP IS THE NEUTRAL SEAT REFERENCE POINT AND BRP IS THE BUTTOCK REFERENCE POINT (REFERENCE MIL-STD-1333).

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~~FIGURE 14. SEAT DIMENSIONAL LIMITS (THIS FIGURE ONLY PRESENTS MAX-MIN DIMENSIONAL PARAMETERS AND IS NOT INTENDED TO REPRESENT DESIGN)~~

RATIONALE FOR SPECIFICATION CHANGES

1. Nylon should not be used due to its high elongation and elasticity.

2. Quick disconnect specified is of inadequate strength for crashworthy gunner seats.

3. Statement clarification.

4. Gunner cannot perform operation while restrained in a fixed seat. The gunner is required to move away from the seat yet should be restrained to the seat.

5. V_O (no penetration) is not practical.

6. Requirement added for type II and type III seats to be convertible which is just inferred by the statement.

7. Armored seats or seats mounted on tracks are too heavy or too complex to be removed by one man and without the use of standard tools.

8. Clarification to remove impression seat fabric should be drum-tight. Drum-tight fabric decreases comfort and increases loading on seat pan frame. Spreaders under seat fabric are associated only with conventional troop seats.

9. Quick disconnects in accordance with MIL-A-21165 will not withstand crashworthy troop seat loads, and quick disconnects are not practical for armored or complex gunner seats.

10. Reference to seat legs removed, as crashworthy gunner seats may not have legs.

11. Clarification of seat mounting priority to emphasize that seats should not have energy attenuators in series (above and below the seat), as they will not stroke simultaneously.

12. Seat rotation requirements added.

13. Seat accommodation requirements added.

14. 50th percentile data included with 95th percentile data (6.3.2).

15. Allowance of up to 60 percent reduction of crash impulse permitted by this paragraph is not realistic due to low efficiency of crushing aircraft structure acting as an energy attenuator.

16. Seats designed for 14.5G vertical stroking load cannot be subjected to higher loads unless stops are provided at a point before seat pan contacts the floor.

17. Rotating seats must be designed for the higher forward loading condition for all sides capable of being oriented toward the front of the aircraft.

18. Twelve-inch vertical seat stroke is inadequate for troop/gunner seats due to the wide range of occupant and equipment weights,and ceiling deformation reduces seat stroke efficiency for ceiling suspended seats.

19. Added desirability for energy attenuating provisions in other than vertical axis.

20. Flush stowage of restraint system is not necessary to prevent encumbrance during ingress or egress. Side straps and lap belt tiedown straps are not compatible with gunner operations restraint system. Attachment of buckle to other than lap belt adds too much complexity for inexperienced troops who may use gunner seat. A positioning strap is required to prevent lap belt buckle from riding up during gunner operations.

21. Independent shoulder strap retraction and accessibility necessary to facilitate donning.

22. Loops in restraint harness will snag troop and gunner equipment.

23. Percent elongation of webbing cannot be determined when given in inches due to the variable strap lengths. Strap loads revised per stress analysis. Tables 1 and 2 combined.

24. Revised to include reel at lap belt anchor and reel requirements.

25. Inverted-Y strap requirement added to prevent shoulder straps from slipping off shoulder.

26. Lap belt tiedown strap is not compatible with gunner motion restraint system.

27. Not applicable to inverted-Y strap system.

28. Paragraph number corrected.

29. Lift lever requirement and requirement for ejector feature added to buckle.

30. Shoulder harness reel requirements added.

31. Gunner seats can be designed for lighter weights than those specified.

32. Placard data added.

33. Figure number corrected.

34. Mockup requirements added.

35. Combat equipment and weights updated.

36. Test on seats without vertical guides unjustifiably complicated by sequenced load application.

37. Vertical energy attenuators determine maximum load that can be applied in predominantly vertical load application.

38. Curvilinear deformation curve used to accommodate high elongation cables for lateral energy attenuation.

39. Acceptable and unacceptable note corrected.

40. Maximum acceleration added.

41. Restraint figure updated with additional requirements.

42. Figure 13 revised to agree with Figure 3 and TR 71-22 and MIL-S-58095.

43. Limitation dimensions and tolerances added to Figure 14.

CRASH SURVIVAL DESIGN GUIDE (TR 71-22)

Modifications were recommended to USAAMRDL TR 71-22 Crash Survival Design Guide.

The affected paragraphs of TR 71-22 have been reproduced, and the recommended changes are noted by crosshatching (////) portions deleted and underlining (_____) added portions.

3.3.2.1 The same percentile range of occupant sizes should be considered for troop and gunner seat design. ~~Since more flexibility is available in the design of troop seats, the typically large clothing and equipment variations for troops should be considered.~~ Since a greater range of clothing and equipment is used by troops than by aviators, troop and troop/gunner seats should be designed to accommodate these variations. The 95th percentile occupant should be considered heavily clothed and equipped, while the 5th percentile occupant should be considered lightly clothed and equipped. ~~Based on data contained in References 22 and 23,~~ It is not reasonable, however, to design a crashworthy troop or gunner seat to accommodate the full range of equipment which can be carried by troops. A subsistence load weight over 90 pounds would be carried in a large rucksack with a Lincloe carrying frame. The depth of such equipment is 17 inches and cannot be accommodated within a reasonable seat depth. Seat design should be limited to accommodations for the size and weight range of troops without equipment, to troops with combat assault equipment. Gunner seats which will also be used by troops will be designed by troop weights. The typical weights of seated troops in aircraft are: (1)

	95th Percentile (lb)	
Soldier	~~192.0~~	202.0
Clothing	~~3.2~~	3.0
Boots	4.0	
~~Protective Vest~~	~~8.5~~	
Helmet	3.0	
~~Equipment~~	~~27.3~~	
~~Field Pack with Sleeping Bag~~	~~17.2~~	30.3
Combat Assault Pack and Equipment not Including Rifle	~~255.2~~	242.3

(2)

	5th Percentile (lb)	
Man	~~121.0~~	126.3
Clothing	2.6	
Boots	4.0	
Helmet	3.0	
	~~131.6~~	135.9

(Revise) Figure 3-23. Seat Forward Load and Deflection Requirements for Forward- or Aft-Facing Crew Seats in ~~for~~ all Types of Army Aircraft (95th Percentile Accidents). 3

(Place this Title under Cockpit Seats)

(Add) Figure 3-23A. Seat Forward Load and Deflection Requirements for Forward-, Aft- or Side-Facing Troop or Gunner Seats in all Types of Army Aircraft (95th Percentile Accidents).

(Revise Figure, Extending Controlled Deformations from 6 to 10 inches)P

3.3.4 LATERAL STRENGTH AND DEFORMATION REQUIREMENTS

The lateral load and deformation requirements for forward- and aft-facing seats are presented in Figure 3-24 for the 95th percentile accident (see Table 1-II in Chapter 1). Two curves are presented. One is for rotary-wing aircraft and the cockpits of large fixed-wing aircraft. The other is for light fixed-wing aircraft and cabins of large fixed-wing aircraft. The deflections are to be measured at the neutral seat reference point. Occupant weight should be as stated in paragraph 3.3.1. Controlled deformation for side-facing seats may be increased from the 4 inches shown to 10 inches. 4

Figure 3-24. Lateral Seat Load and Deformation Requirements for Forward- or Aft-Facing Seats in all Types of Army Aircraft (95th Percentile Accident). 4

Figure 3-24. (Revise Base Curve to Curvilinear Shape) 5

3.5.2 SEAT COMPONENT ATTACHMENT

Since components that break free during a crash can become lethal weapons, it is recommended that attachment strengths be

consistent with those specified for ancillary equipment. Static attachment strengths for components, e.g., armored panels, should therefore be as follows:

Downward:	35G
Upward:	15G
Forward:	35G
Aftward:	15G
Lateral:	20G

These criteria may be somewhat conservative for load-limited seats. ~~However~~ Load limiting is mandatory in the vertical direction only. ~~In light of the potential hazard, the strength requirements are felt to be justified.~~ Therefore, these loads shall apply only to the seats that are not load limited. The loads will apply, however, to load-limited seats in the directions that have no load-limiting provisions. 6

TABLE 3-II. SEAT DESIGN AND STATIC TEST REQUIREMENTS

Test Ref No.	Loading Direction with Respect to Fuselage Floor	Load Required	Deformation Requirements[a]
1	Forward	See Figure 3-23	See Figure 3-23
2	Aftward	12G Minimum	No Requirement
3	Lateral[b]	See Figure 3-24	See Figure 3-24
4	Downward/		
	Crew Seat	14.5 $+1.0G$[d,e]	See Paragraph
	Troop and gunner Seat	14.5 $\mp 1.0G$[d]	3.3.3.1
5	Upward	8G Minimum	No Requirement
6	Forward[c,f]	See Figure 3-23[c]	See Figure 3-23
	Downward/		
Com-bined	Crew Seat	14.5 $+2.0G$	Same as Test 4
	Troop and gunner Seat	14.5 $\mp 2.0G$	
	Lateral[f]	9G Minimum	No Requirements

a. The aircraft floor or sidewall should be deformed in the xz and yz planes, as detailed in paragraph 3.2.4.4 and in Figure 3-27, simultaneously with the "G" loads specified.

b. The lateral loads should be applied in the direction which is most critical. In the case of symmetrical seats, the loading direction is optional.

c. In the event that no load-limiting device is used in the forward direction, a 20G load for cabin seats and a 25G load for crew seats may be used for this combined loading.

d. If more than one load-limiter setting is provided, each should be tested.

e. Subsequent to the stroking of the vertical energy-absorber device, the seat should carry a vertical static load of 25G, based on the effective weight of the 95th percentile occupant plus seat and equipment, without loss of attachment to the basic structure/ except when the seat pan is resting on the floor. Plastic deformation is acceptable in this test. 7

f. The forward and lateral loads should be applied prior to the downward load application/ on seats employing vertical slide tubes or guides. 8

RATIONALE FOR CHANGES TO TR 71-22

1. To limit the range of equipment for which troop and gunner seats should be designed. The large rucksack with Lincloe frame is 17 inches deep, which is excessive for the seat depth limitations and cabin space specified by the using agencies.

2. Weight of 95th percentile troop increased 10 pounds per Natick Labs Report 72-51-CE. Troop equipment weight for combat assault operation is reduced 23 pounds, which includes weight of sleeping bag and protective vest (not used on combat assault operations) and rifle which is not effective on seat load.

3. Figure 3-23 curve not applicable to side-facing seats due to lower lateral human tolerance. Figure 3-23 deflection requirements not applicable to troops and gunner seats due to higher troop equipment weight range and low weight of troop seats and unarmored gunner seats.

4. Lateral deformation curve (Figure 3-24) not applicable to side-facing seats due to lower lateral human tolerance.

5. Base curve shown in Figure 3-24 not achievable with light tension yielding energy attenuators suitable to light troop and gunner seats.

6. Design for loads considerably above the load-limited loads on lightweight seats imposes a severe weight penalty.

7. Vertical static load requirements considerably above the load-limited load on all seats is unnecessarily costly in weight if the seat bottoms out on the floor before the energy attenuator bottoms.

8. Seats not subject to vertical binding due to horizontal distortion should not be subjected to unnecessary test.

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APPENDIX A
TABULATION OF QUESTIONNAIRE RESULTS

This appendix presents the detailed results of the questionnaire survey. The data are presented by type of aircraft and classification of personnel. Total responses to each question are presented on the actual questionnaire forms that were circulated.

GUNNER SEAT QUESTIONNAIRE

Answer questions for a specific aircraft. Use additional forms for other aircraft. Check NO OPINION column if you have had no experience with question.

1. Aircraft on which answers based ____________
2. Type of pintle mounted gun used in this aircraft ____________
3. Experience with this aircraft was in

☐ RVN ☐ CONUS
☐ EUROPE ☐ OTHER ________

	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION	COMMENTS
PROVISIONS							
1. Are gunner seats provided at the gunner stations	1	0	1	2	6	1	
2. Are seats improvised in the field at gunner stations if no seats are provided	0	2	2	0	5	4	GROUP I
3. Is a seat provided for the gunner at other than the gunner station - type	3	2	2	0	1	4	UH-I
4. Are spent cartridge case containers provided	4	3	0	3	1	1	
5. Are stops provided on gun installations to prevent ballistic impacts with the aircraft or rotor	3	0	0	4	5	0	12 Gunners/Crewchiefs
OPERATION							
1. Does the gunner stand to operate the gun at the gunner station	2	9	1	0	0	0	
2. Does the gunner sight through the gunsights when operating the gun	5	4	2	1	0	0	
3. If a fixed seat is provided does the gunner slide sideways on the seat while operating the gun in azimuth, i.e. swinging from side-to-side	1	4	0	6	1	0	
4. If a seat is provided does the gunner rise up off the seat when operating the gun in elevation	1	3	0	6	1	1	
5. Is depressed angle operation encumbered by ceiling height	3	2	0	4	0	3	
6. Is azimuth traverse firing encumbered by window or door opening width	7	2	0	1	0	1	

GROUP I

UH-I

Gunners/Crewchiefs

	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION
7. Does the gunner extend head or shoulders outside the aircraft to aim or fire gun	3	3	3	2	1	0
8. Does the gunner spend most of the flight time at the gunner station	0	1	0	1	10	0
9. Is motion of the gun encumbered by the ammunition chute	3	2	1	3	1	2
10. Do spent cartridge case containers (if provided) encumber the gunners motions	3	3	1	2	1	1
11. Are tracers used to assist in aiming gun	2	0	0	6	4	0
RESTRAINT						
1. Is a safety lanyard and harness provided when operating the gun	0	4	1	1	5	0
2. Is the gunner strapped to the seat (if seat is provided) while operating the gun	3	2	1	3	3	0
3. Does the gunner fasten lap belt loosely (if seat is provided) while operating the gun	3	1	0	3	4	0
4. Is the gunner seat (if provided) equipped with a lap belt	1	1	1	2	5	0

OPINIONS

1. What is the optimum gunsight height when gun is level: eye level __2__, neck level __0__, chest level __7__, abdomen level __2__, other __0__, where __0__.

2. What should be the minimum clearance between the end of the gun and the front of the gunner __12 in__

(12) - 6
(18) - 1
(24) - 1
(36) - 1

3. Which would you prefer?

 1 Horizontally movable seat and pintle mounted gun fixed at one point

 5 Fixed seat and gun with horizontally movable pintle mount

 4 Fixed seat and pintle mounted gun fixed at one point

4. Which would you prefer?

 1 Elevating seat and pintle mounted gun fixed at one point

 5 Fixed seat and gun with vertically movable pintle mount

 3 Fixed seat and pintle mounted gun fixed at one point

5. Which would you prefer?

 8 A fixed seat with a safety ("monkey") harness worn by the gunner which is attached to the seat allowing the gunner to stand and operate the door gun?

 2 A moveable seat within which the gunner sits, restrained by a lap belt and shoulder harness while operating the door gun?

 0 No seat, but make a safety ("monkey") harness available at the gunner station to prevent the gunner from falling out of the aircraft?

 0 No seat and no restraint (safety) harness at all? Why? ________

Do you consider the concept you prefer to be practical? Yes 8 , No 0 , If no, why not? ________

6. Do you believe that helicopters with side-facing door gunner stations and armored pilot/co-pilot seats should also provide a seat with armor protect. for each door gunner? Yes 9 , No 1 , If not, why? ________

7. Number the following locations for placing armor relative to the gunner in order of priority

Back 3rd , Bottom 1st , Forward Side 5th ,

Rearward Side 4th , Front 2nd .

8. Remarks:

BACK	BOTTOM	FWD SIDE	REARWARD SIDE	FRONT
(1)-1	(1)-8	(3)-3	(3)-4	(1)-1
(2)-3	(2)-2	(4)-4	(4)-3	(2)-4
(3)-2			(5)-2	(4)-2
(5)-3				(5)-1

GUNNER SEAT QUESTIONNAIRE

Answer questions for a specific aircraft. Use additional forms for other aircraft. Check NO OPINION column if you have had no experience with question.

1. Aircraft on which answers based ______________
2. Type of pintle mounted gun used in this aircraft ______________
3. Experience with this aircraft was in

☐ RVN ☐ CONUS
☐ EUROPE ☐ OTHER ________

	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION	COMMENTS
PROVISIONS							
1. Are gunner seats provided at the gunner stations	11	1	2	3	33	0	
2. Are seats improvised in the field at gunner stations if no seats are provided	10	11	0	4	8	14	GROUP 2 UH-1
3. Is a seat provided for the gunner at other than the gunner station - type	19	12	1	4	5	7	
4. Are spent cartridge case containers provided	9	11	6	14	8	1	49 PILOTS & OTHERS
5. Are stops provided on gun installations to prevent ballistic impacts with the aircraft or rotor	9	3	5	8	23	0	
OPERATION							
1. Does the gunner stand to operate the gun at the gunner station	12	22	5	9	1	0	
2. Does the gunner sight through the gunsights when operating the gun	13	21	5	7	2	0	
3. If a fixed seat is provided does the gunner slide sideways on the seat while operating the gun in azimuth, i.e. swinging from side-to-side	1	9	5	23	8	2	
4. If a seat is provided does the gunner rise up off the seat when operating the gun in elevation	5	10	7	21	6	0	
5. Is depressed angle operation encumbered by ceiling height	23	10	4	7	2	3	
6. Is azimuth traverse firing encumbered by window or door opening width	25	12	[illegible]	5	[illegible]	2	

	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION
7. Does the gunner extend head or shoulders outside the aircraft to aim or fire gun	1	20	7	18	3	0
8. Does the gunner spend most of the flight time at the gunner station	1	0	0	25	22	1
9. Is motion of the gun encumbered by the ammunition chute	7	13	7	14	1	7
10. Do spent cartridge case containers (if provided) encumber the gunners motions	6	16	6	10	1	9
11. Are tracers used to assist in aiming gun	0	1	0	15	31	1
RESTRAINT						
1. Is a safety lanyard and harness provided when operating the gun	2	14	7	[illegible]	14	0
2. Is the gunner strapped to the seat (if seat is provided) while operating the gun	7	13	5	14	9	0
3. Does the gunner fasten lap belt loosely (if seat is provided) while operating the gun	5	8	7	21	4	4
4. Is the gunner seat (if provided) equipped with a lap belt	0	1	1	11	29	5

GROUP 2

UH-1

PILOTS & OTHERS

OPINIONS

1. What is the optimum gunsight height when gun is level: eye level 5, neck level 9, chest level 27, abdomen level 6, other 2, where 0.
2. What should be the minimum clearance between the end of the gun and the front of the gunner ____
   8 in. - 1
   12 in. - 10
   18 in. - 10
   24 in. - 10

3. Which would you prefer?

 19 Horizontally movable seat and pintle mounted gun fixed at one point
 19 Fixed seat and gun with horizontally movable pintle mount
 13 Fixed seat and pintle mounted gun fixed at one point

4. Which would you prefer?

 11 Elevating seat and pintle mounted gun fixed at one point
 24 Fixed seat and gun with vertically movable pintle mount
 12 Fixed seat and pintle mounted gun fixed at one point

5. Which would you prefer?

 29 A fixed seat with a safety ("monkey") harness worn by the gunner which is attached to the seat allowing the gunner to stand and operate the door gun?

 21 A moveable seat within which the gunner sits, restrained by a lap belt and shoulder harness while operating the door gun?

 0 No seat, but make a safety ("monkey") harness available at the gunner station to prevent the gunner from falling out of the aircraft?

 0 No seat and no restraint (safety) harness at all? Why? ________

Do you consider the concept you prefer to be practical? Yes 48 , No 2 , If no, why not? ________________

6. Do you believe that helicopters with side-facing door gunner stations and armored pilot/co-pilot seats should also provide a seat with armor protection for each door gunner? Yes ______, No ______, If not, why? ______________

7. Number the following locations for placing armor relative to the gunner in order of priority

Back 1st , Bottom 2nd , Forward Side 4th ,

Rearward Side 5th , Front 3rd .

8. Remarks:

BACK	BOTTOM	FORWARD SIDE	REARWARD SIDE	FRONT
(1) - 8	(1) - 5	(2) - 2	(2) - 1	(1) - 2
(3) - 1	(2) - 10	(3) - 7	(4) - 2	(2) - 3
(5) - 1		(4) - 3	(5) - 3	(3) - 1
				(5) - 3

GROUP 3

CH-46

GUNNERS/CREWCHIEFS

	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION
7. Does the gunner extend head or shoulders outside the aircraft to aim or fire gun	33	4	0	0	1	0
8. Does the gunner spend most of the flight time at the gunner station	1	2	6	18	10	0
9. Is motion of the gun encumbered by the ammunition chute	17	6	1	1	6	4
10. Do spent cartridge case containers (if provided) encumber the gunners motions	18	6	1	1	8	2
11. Are tracers used to assist in aiming gun	1	0	0	5	31	0
RESTRAINT						
1. Is a safety lanyard and harness provided when operating the gun	10	1	2	3	19	2
2. Is the gunner strapped to the seat (if seat is provided) while operating the gun	19	1	0	0	0	17
3. Does the gunner fasten lap belt loosely (if seat is provided) while operating the gun	11	1	0	2	2	21
4. Is the gunner seat (if provided) equipped with a lap belt	8	1	0	0	1	24

OPINIONS

1. What is the optimum gunsight height when gun is level: eye level 1, neck level 3, chest level 18, abdomen level 15, other 0, where ______.
2. What should be the minimum clearance between the end of the gun and the front of the gunner 12 in

6 in. - 3
10 in. - 1
12 in. - 10
16 in. - 1
18 in. - 4
20 in. - 1
24 in. - 5
No opinion - 12

GUNNER SEAT QUESTIONNAIRE

Answer questions for a specific aircraft. Use additional forms for other aircraft. Check NO OPINION column if you have had no experience with question.

1. Aircraft on which answers based ____________
2. Type of pintle mounted gun used in this aircraft ____________
3. Experience with this aircraft was in

☐ RVN ☐ CONUS

☐ EUROPE ☐ OTHER ____________

	NEVER OR NO (0%)	OCCASIONALLY (25%)	AVERAGE (50%)	FREQUENTLY (75%)	ALWAYS (100%)	NO OPINION	COMMENTS
PROVISIONS							
1. Are gunner seats provided at the gunner stations	36	0	0	1	0	0	GROUP 3
2. Are seats improvised in the field at gunner stations if no seats are provided	10	17	1	6	4	0	CH-46
3. Is a seat provided for the gunner at other than the gunner station - type	11	1	2	3	15	1	
4. Are spent cartridge case containers provided	2	4	2	11	17	0	38 GUNNERS/CREWCHIEF
5. Are stops provided on gun installations to prevent ballistic impacts with the aircraft or rotor	0	1	0	1	30	0	
OPERATION							
1. Does the gunner stand to operate the gun at the gunner station	1	3	2	3	28	0	
2. Does the gunner sight through the gunsights when operating the gun	13	11	7	5	0	1	
3. If a fixed seat is provided does the gunner slide sideways on the seat while operating the gun in azimuth, i.e. swinging from side-to-side	9	2	0	1	5	16	
4. If a seat is provided does the gunner rise up off the seat when operating the gun in elevation	2	2	1	3	10	17	
5. Is depressed angle operation encumbered by ceiling height	19	7	1	3	1	4	
6. Is azimuth traverse firing encumbered by window or door opening width	14	6	4	8	2	1	

3. Which would you prefer?

14 Horizontally movable seat and pintle mounted gun fixed at one point

12 Fixed seat and gun with horizontally movable pintle mount

6 Fixed seat and pintle mounted gun fixed at one point

2 No Opinion

4. Which would you prefer?

16 Elevating seat and pintle mounted gun fixed at one point

11 Fixed seat and gun with vertically movable pintle mount

4 Fixed seat and pintle mounted gun fixed at one point

3 No Opinion

5. Which would you prefer?

16 A fixed seat with a safety ("monkey") harness worn by the gunner which is attached to the seat allowing the gunner to stand and operate the door gun?

14 A moveable seat within which the gunner sits, restrained by a lap belt and shoulder harness while operating the door gun?

6 No seat, but make a safety ("monkey") harness available at the gunner station to prevent the gunner from falling out of the aircraft?

1 No seat and no restraint (safety) harness at all? Why? __________

Do you consider the concept you prefer to be practical? Yes 28, No 5, If no, why not? __________

6. Do you believe that helicopters with side-facing door gunner stations and armored pilot/co-pilot seats should also provide a seat with armor protect for each door gunner? Yes 20, No 15, If not, why? __________
1 No Opinion

7. Number the following locations for placing armor relative to the gunner in order of priority

Back 3rd, Bottom 1st, Forward Side 5th,

Rearward Side 4th, Front 2nd.

8. Remarks:

BACK	BOTTOM	FWD SIDE	REARSIDE	FRONT
(1) - 3	(1) - 23	(1) - 1	(2) - 3	(1) - 7
(2) - 4	(2) - 6	(2) - 2	(3) - 7	(2) - 11
(3) - 8	(2) - 2	(3) - 6	(4) - 10	(3) - 2
(4) - 3		(4) - 4		

GUNNER SEAT QUESTIONNAIRE

Answer questions for a specific aircraft. Use additional forms for other aircraft. Check NO OPINION column if you have had no experience with question.

1. Aircraft on which answers based ____________________
2. Type of pintle mounted gun used in this aircraft ____________________
3. Experience with this aircraft was in

☐ RVN ☐ CONUS
☐ EUROPE ☐ OTHER __________

	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION	COMMENTS
PROVISIONS							
1. Are gunner seats provided at the gunner stations	25	0	1	0	0	0	
2. Are seats improvised in the field at gunner stations if no seats are provided	1	1	1	0	25	0	GROUP 4
3. Is a seat provided for the gunner at other than the gunner station - type	14	2	1	2	7	2	CH-47
4. Are spent cartridge case containers provided	4	4	1	9	9	0	27 PILOTS
5. Are stops provided on gun installations to prevent ballistic impacts with the aircraft or rotor	3	1	0	2	21	1	
OPERATION							
1. Does the gunner stand to operate the gun at the gunner station	1	4	6	9	7	0	
2. Does the gunner sight through the gunsights when operating the gun	6	11	3	3	0	4	
3. If a fixed seat is provided does the gunner slide sideways on the seat while operating the gun in azimuth, i.e. swinging from side-to-side	6	5	6	2	3	8	
4. If a seat is provided does the gunner rise up off the seat when operating the gun in elevation	4	3	1	8	6	15	
5. Is depressed angle operation encumbered by ceiling height	18	2	2	0	1	12	
6. Is azimuth traverse firing encumbered by window or door opening width	9	3	4	3	4	4	

GROUP 4

CH-47

PILOTS

Item	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION
7. Does the gunner extend head or shoulders outside the aircraft to aim or fire gun	11	10	3	1	1	2
8. Does the gunner spend most of the flight time at the gunner station	0	0	1	9	16	1
9. Is motion of the gun encumbered by the ammunition chute	10	7	4	2	2	2
10. Do spent cartridge case containers (if provided) encumber the gunners motions	7	9	4	2	1	4
11. Are tracers used to assist in aiming gun	0	1	3	6	16	0
RESTRAINT						
1. Is a safety lanyard and harness provided when operating the gun	10	7	4	4	2	0
2. Is the gunner strapped to the seat (if seat is provided) while operating the gun	17	5	2	0	2	1
3. Does the gunner fasten lap belt loosely (if seat is provided) while operating the gun	11	6	1	1	3	4
4. Is the gunner seat (if provided) equipped with a lap belt	11	7	0	1	3	4

OPINIONS

1. What is the optimum gunsight height when gun is level: eye level __0__, neck level __3__, chest level __8__, abdomen level __13__, other __0__, where __0 No Opinion-2__.
2. What should be the minimum clearance between the end of the gun and the front of the gunner __12 in.__

   (6 in.) - 2
   (8 in.) - 3   No Opinion - 3
   (12 in.) - 13
   (15 in.) - 1
   (18 in.) - 3

3. Which would you prefer?

12 Horizontally movable seat and pintle mounted gun fixed at one point
6 Fixed seat and gun with horizontally movable pintle mount
7 Fixed seat and pintle mounted gun fixed at one point

4. Which would you prefer?

15 Elevating seat and pintle mounted gun fixed at one point
3 Fixed seat and gun with vertically movable pintle mount
7 Fixed seat and pintle mounted gun fixed at one point

5. Which would you prefer?

11 A fixed seat with a safety ("monkey") harness worn by the gunner which is attached to the seat allowing the gunner to stand and operate the door gun?

16 A moveable seat within which the gunner sits, restrained by a lap belt and shoulder harness while operating the door gun?

0 No seat, but make a safety ("monkey") harness available at the gunner station to prevent the gunner from falling out of the aircraft?

0 No seat and no restraint (safety) harness at all? Why? ________

Do you consider the concept you prefer to be practical? Yes 25 , No 1 , If no, why not? ________

6. Do you believe that helicopters with side-facing door gunner stations and armored pilot/co-pilot seats should also provide a seat with armor protect for each door gunner? Yes 21 , No 6 , If not, why? ________

7. Number the following locations for placing armor relative to the gunner in order of priority

Back 3rd , Bottom 1st , Forward Side 4th ,

Rearward Side 5th , Front 2nd .

8. Remarks:

BACK	BOTTOM	FWD SIDE	REARWARD SIDE	FRONT
(2) -4	(1) -17	(1) -3	(2) -3	(1) -6
(3) -6	(2) -33	(2) -4	(3) -2	(2) -7
(4) -7	(3) -4	(3) -4	(4) -6	(3) -4
(5) -2		(4) -3	(5) -8	(4) -1
		(5) -5		(5) -3

GUNNER SEAT QUESTIONNAIRE

Answer questions for a specific aircraft. Use additional forms for other aircraft. Check NO OPINION column if you have had no experience with question.

1. Aircraft on which answers based ______
2. Type of pintle mounted gun used in this aircraft ______
3. Experience with this aircraft was in

☐ RVN ☐ CONUS

☐ EUROPE ☐ OTHER ______

	NEVER OR NO 0%	OCCASIONALLY 25%	AVERAGE 50%	FREQUENTLY 75%	ALWAYS 100%	NO OPINION	COMMENTS
PROVISIONS							
1. Are gunner seats provided at the gunner stations	16	0	0	0	0	0	
2. Are seats improvised in the field at gunner stations if no seats are provided	0	3	0	12	1	0	GROUP 5
3. Is a seat provided for the gunner at other than the gunner station - type	13	0	1	0	1	0	CH-47
4. Are spent cartridge case containers provided	9	3	0	1	3	0	16 GUNNERS/CREWCHIEFS
5. Are stops provided on gun installations to prevent ballistic impacts with the aircraft or rotor	0	0	0	0	0	0	
OPERATION							
1. Does the gunner stand to operate the gun at the gunner station	0	3	5	6	2	0	
2. Does the gunner sight through the gunsights when operating the gun	3	5	6	2	0	0	
3. If a fixed seat is provided does the gunner slide sideways on the seat while operating the gun in azimuth, i.e. swinging from side-to-side	0	0	0	1	0	15	
4. If a seat is provided does the gunner rise up off the seat when operating the gun in elevation	0	1	0	0	2	13	
5. Is depressed angle operation encumbered by ceiling height	13	0	1	1	0	1	
6. Is azimuth traverse firing encumbered by window or door opening width	10	5	0	0	1	0	

Question	NEVER OR NO (0%)	OCCASIONALLY (25%)	AVERAGE (50%)	FREQUENTLY (75%)	ALWAYS (100%)	NO OPINION
7. Does the gunner extend head or shoulders outside the aircraft to aim or fire gun	12	2	1	1	0	0
8. Does the gunner spend most of the flight time at the gunner station	0	0	8	3	5	0
9. Is motion of the gun encumbered by the ammunition chute	3	13	0	0	0	0
10. Do spent cartridge case containers (if provided) encumber the gunners motions	2	2	0	0	0	12
11. Are tracers used to assist in aiming gun	0	0	2	12	2	0
RESTRAINT						
1. Is a safety lanyard and harness provided when operating the gun	13	1	0	2	0	12
2. Is the gunner strapped to the seat (if seat is provided) while operating the gun	1	1	1	0	0	13
3. Does the gunner fasten lap belt loosely (if seat is provided) while operating the gun	1	0	2	0	0	13
4. Is the gunner seat (if provided) equipped with a lap belt	1	0	0	1	0	13

GROUP 5

CH-47

GUNNERS/ CREWCHIEFS

OPINIONS

1. What is the optimum gunsight height when gun is level: eye level 2, neck level 0, chest level 12, abdomen level 2, other 0, where 12 inches.
2. What should be the minimum clearance between the end of the gun and the front of the gunner ____.

   (12 in.) - 9
   (18 in.) - 3
   (24 in.) - 2

   No Opinion
   2

3. Which would you prefer?

1 Horizontally movable seat and pintle mounted gun fixed at one point

2 Fixed seat and gun with horizontally movable pintle mount

13 Fixed seat and pintle mounted gun fixed at one point

4. Which would you prefer?

1 Elevating seat and pintle mounted gun fixed at one point

5 Fixed seat and gun with vertically movable pintle mount

10 Fixed seat and pintle mounted gun fixed at one point

5. Which would you prefer?

13 A fixed seat with a safety ("monkey") harness worn by the gunner which is attached to the seat allowing the gunner to stand and operate the door gun?

2 A moveable seat within which the gunner sits, restrained by a lap belt and shoulder harness while operating the door gun?

0 No seat, but make a safety ("monkey") harness available at the gunner station to prevent the gunner from falling out of the aircraft?

0 No seat and no restraint (safety) harness at all? Why? ______

Do you consider the concept you prefer to be practical? Yes 15, No 0. If no, why not? ______

6. Do you believe that helicopters with side-facing door gunner stations and armored pilot/co-pilot seats should also provide a seat with armor protect for each door gunner? Yes 15, No 1, If not, why? ______

7. Number the following locations for placing armor relative to the gunner in order of priority

Back 3rd, Bottom 2nd, Forward Side 4th,

Rearward Side 5th, Front 1st.

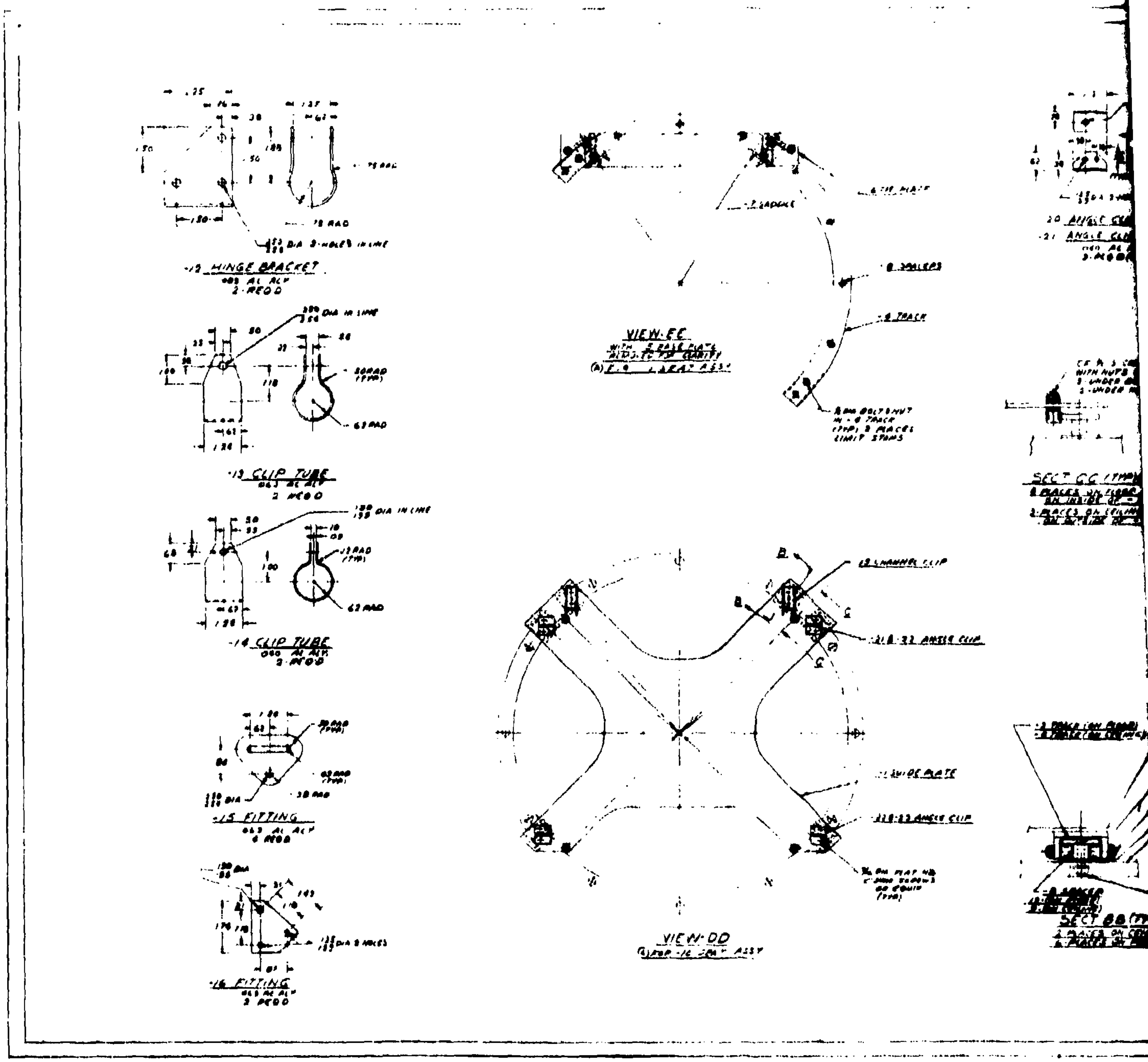
8. Remarks:

BACK	BOTTOM	FWD SIDE	REARWARD SIDE	FRONT
(1) - 3	(2) - 14	(3) - 1	(3) - 1	(1) - 12
		(4) - 1		(5) - 1

APPENDIX B
DETAIL DESIGN DRAWINGS

SWIVEL SEAT MOCKUP DRAWINGS

The swivel seat mockup drawings, SK25067A Sheets 1, 2, and 3, are presented on the following pages.



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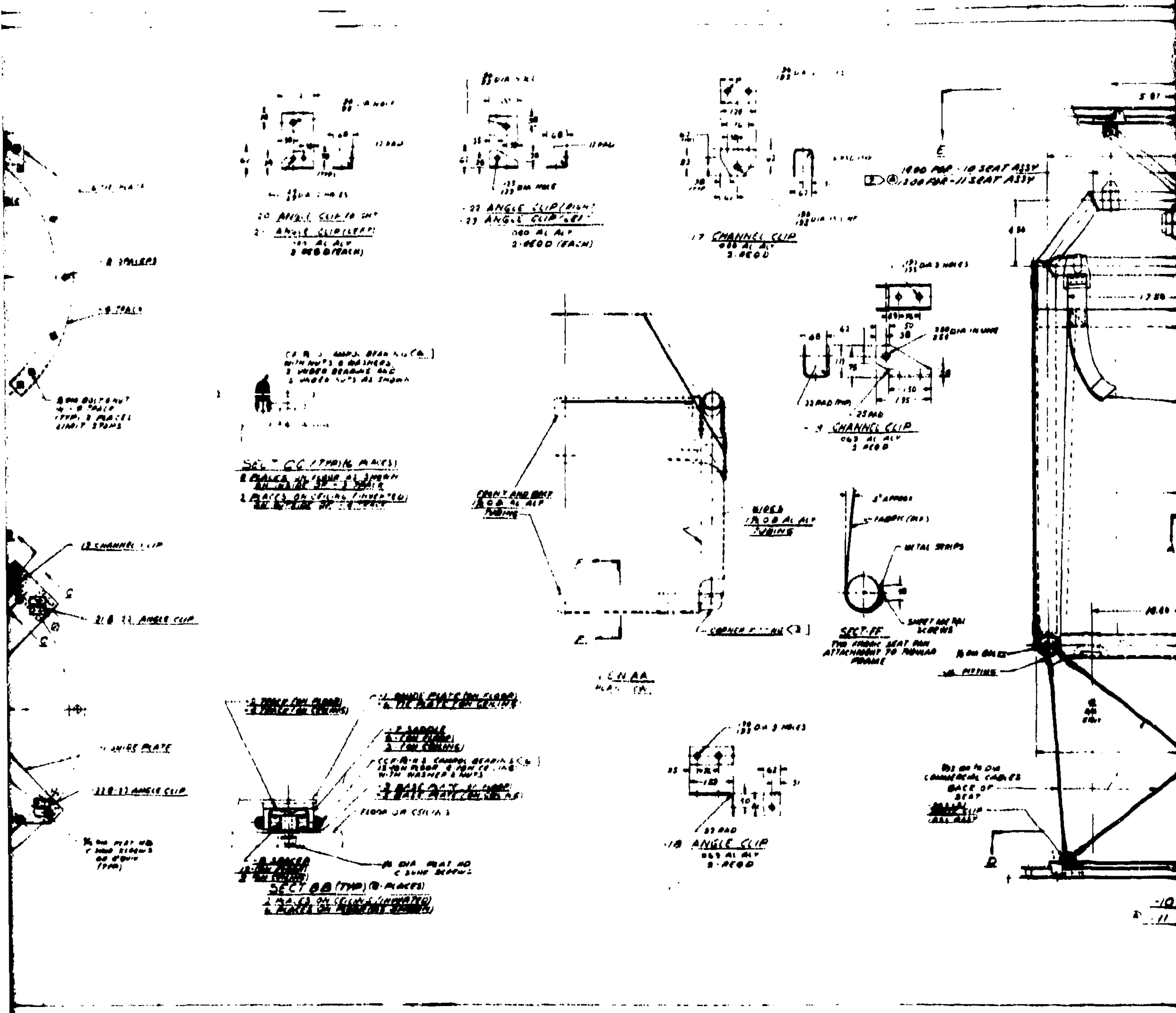

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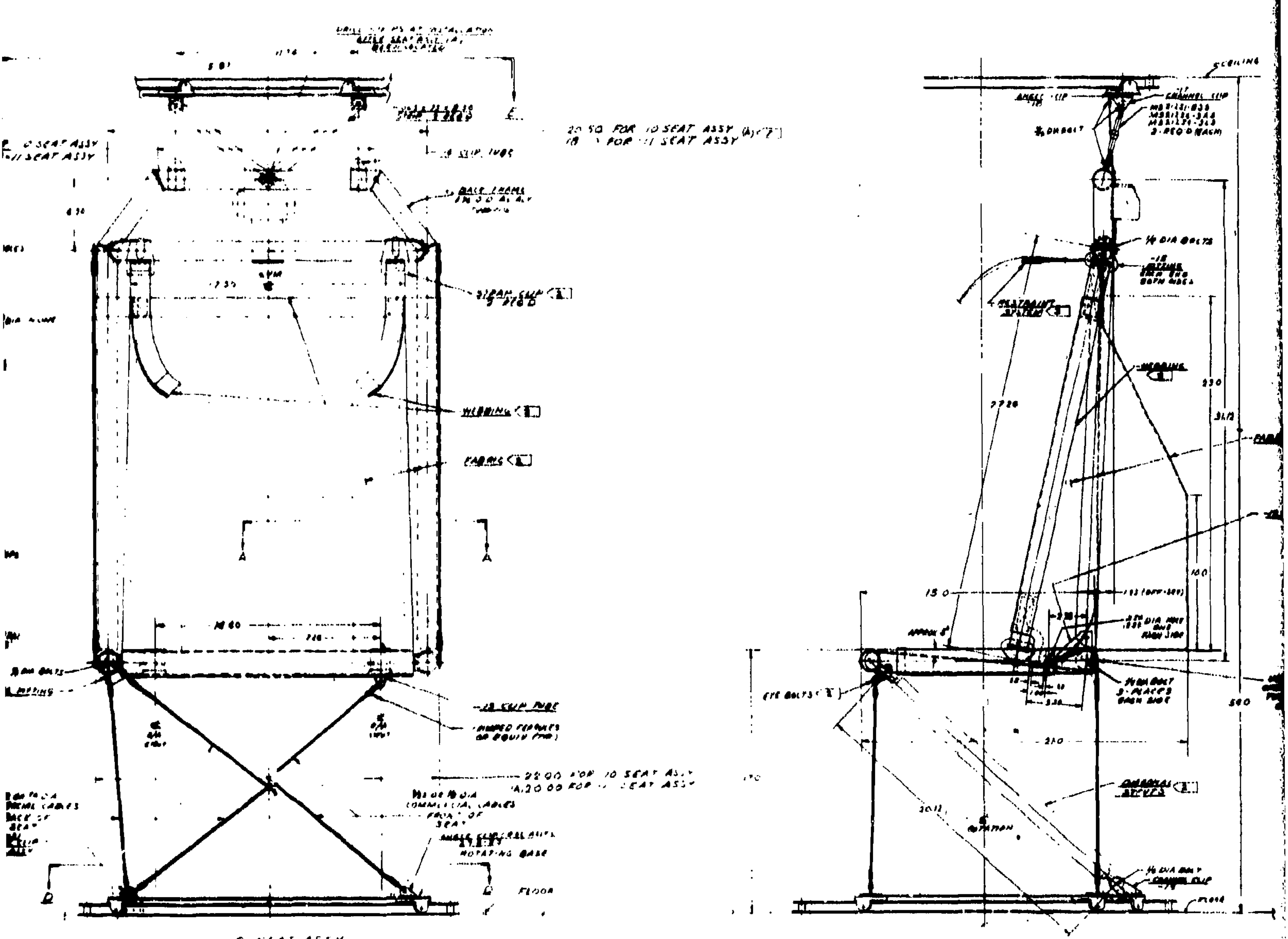
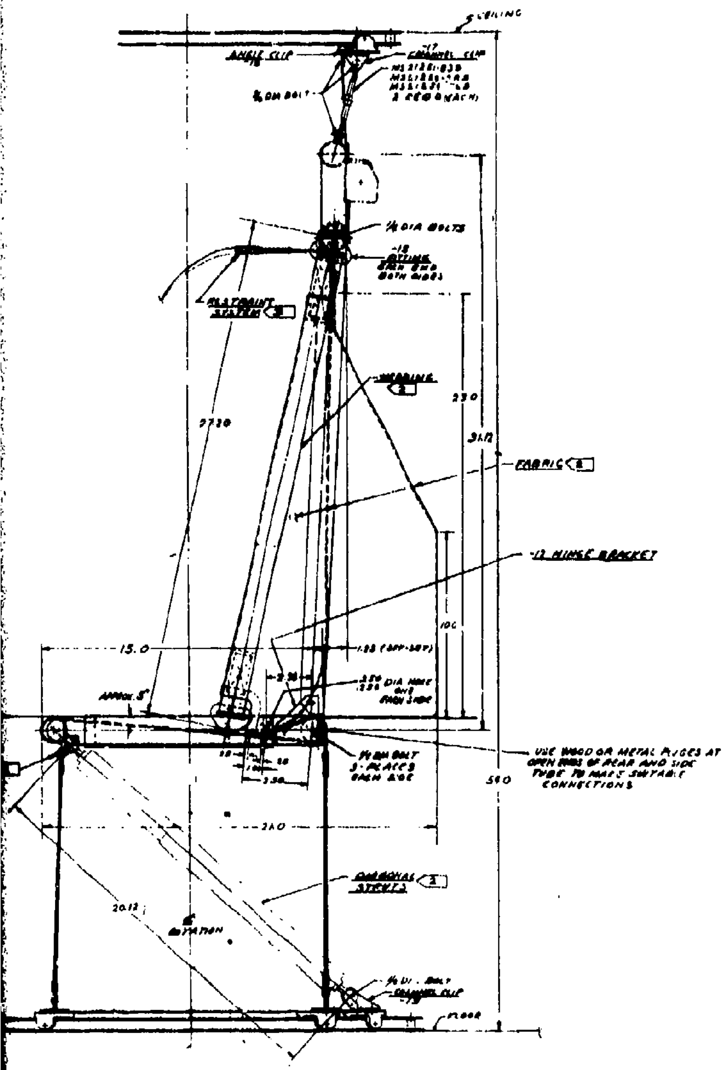


10 SEAT ASSY
11 SEAT ASSY (SEE SHEET 9)



NOTES:

1. BREAK ALL SHARP EDGES AND CORNERS

2. THE FOLLOWING MATERIAL IS TO BE PROVIDED BY BOEING-VERTOL
   - a. WEBBING
   - b. FABRIC
   - c. EYE BOLTS
   - d. CORNER FITTINGS
   - e. DIAGONAL STRUTS
   - f. STRAP TUBE CLIPS

3. RESTRAINT SYSTEM TO BE PROVIDED AND INSTALLED BY BOEING-VERTOL

4. FORMED SHEET METAL PARTS MAY REMAIN IN THE ANNEALED CONDITION.

5. ATTACHMENT OF FABRIC SEAT PAN TO TUBULAR FRAME SHALL BE BY SHEET METAL SCREWS. SEE SECT-"F-F".

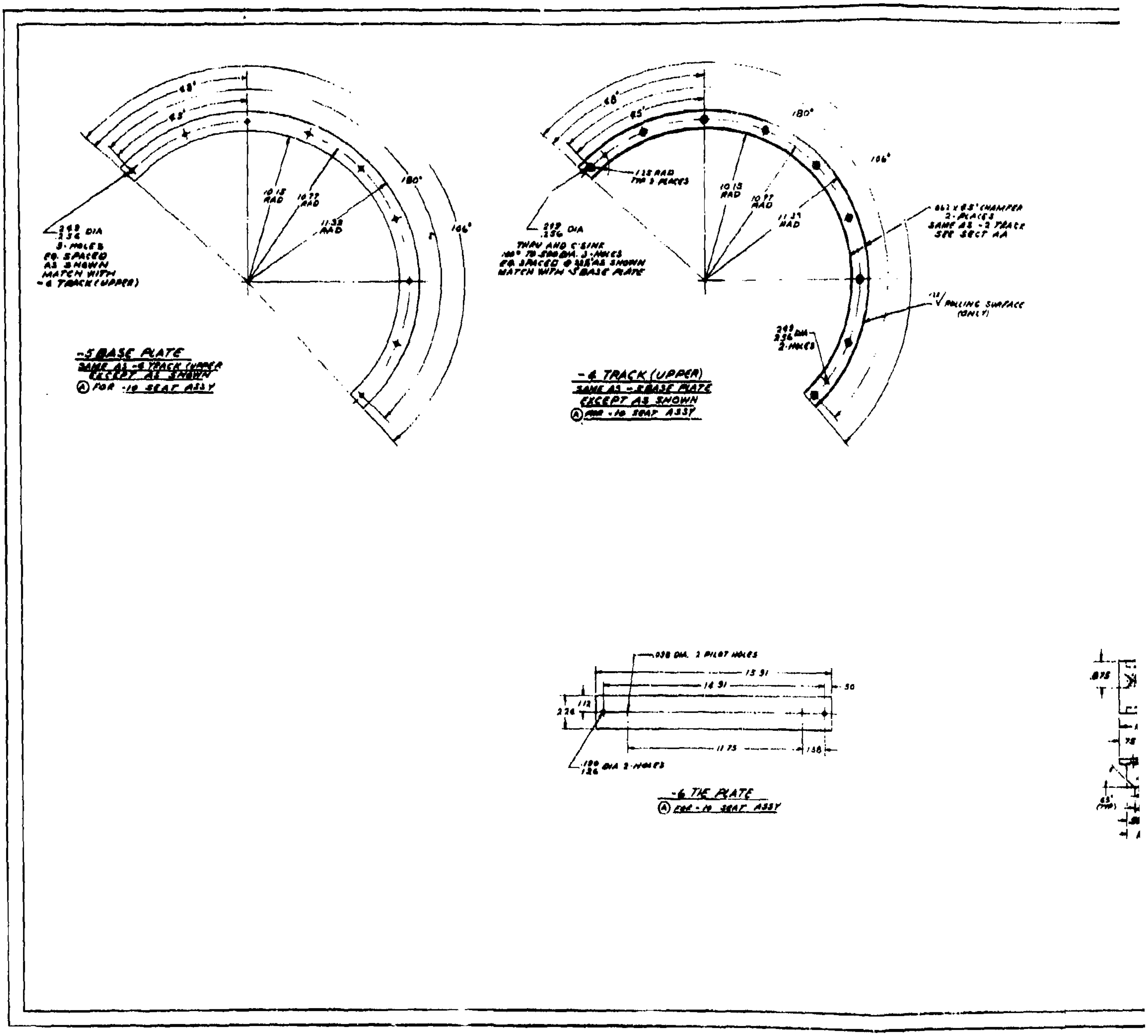
6. CCF-1/2-N-S CAMROL BEARING 16-REQ'D (STOCK ITEM) $2.39 EACH.
   CF-1/2-S CAMROL BEARING 6-REQ'D (STOCK ITEM) $1.98 EACH.
   CAMROL BEARING MAY BE PURCHASED FROM (BEARING INC.) N 8 KATVEN PHILA. MR CARL PANCOST.
   THE ABOVE PRICES WAS A QUOTATION FROM MR ROBERT PARSONS McGILL SALES ENGINEER 1158 CONCORD DRIVE HADDONFIELD, NEW JERSEY 08033 PHONE (215) 363-3885.

(A) 7. MODIFY EXISTING -10 SEAT ASSY FRAME TO MAKE -11 SEAT ASSY. NOTE: -11 SEAT ASSY. IS THE SAME AS -10 SEAT ASSY EXCEPT SEAT WIDTH IS 20.00 WIDE INSTEAD OF 22.00 WIDE AND SEAT LOWER RING ASSY IS SMALLER IN DIA. SEE SHEET 3 OF THIS DWG. FOR DETAILS.

ENERGY ATTENUATING GUNNER SEAT MOCK-UP

77272 SK-25067A

D



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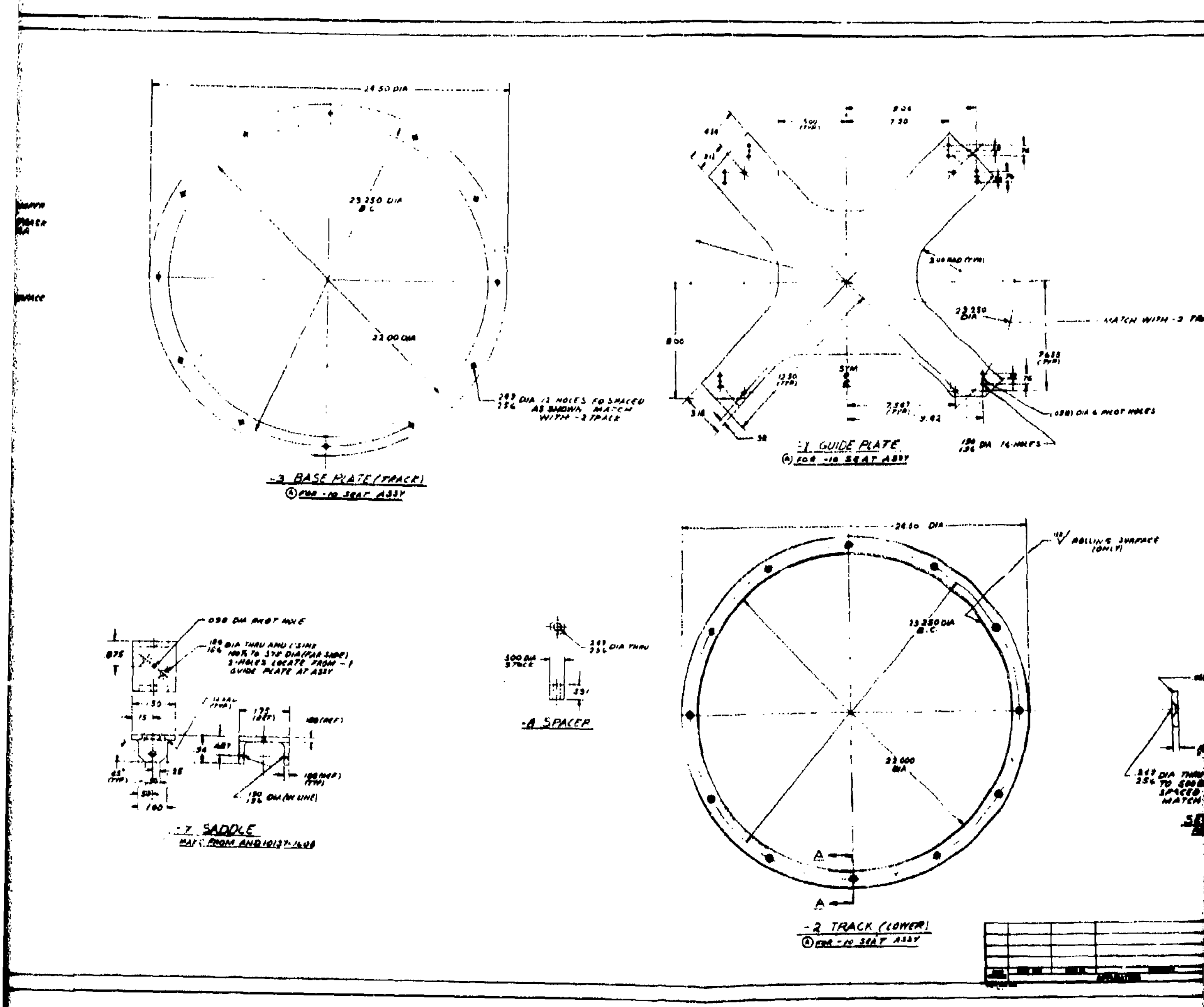
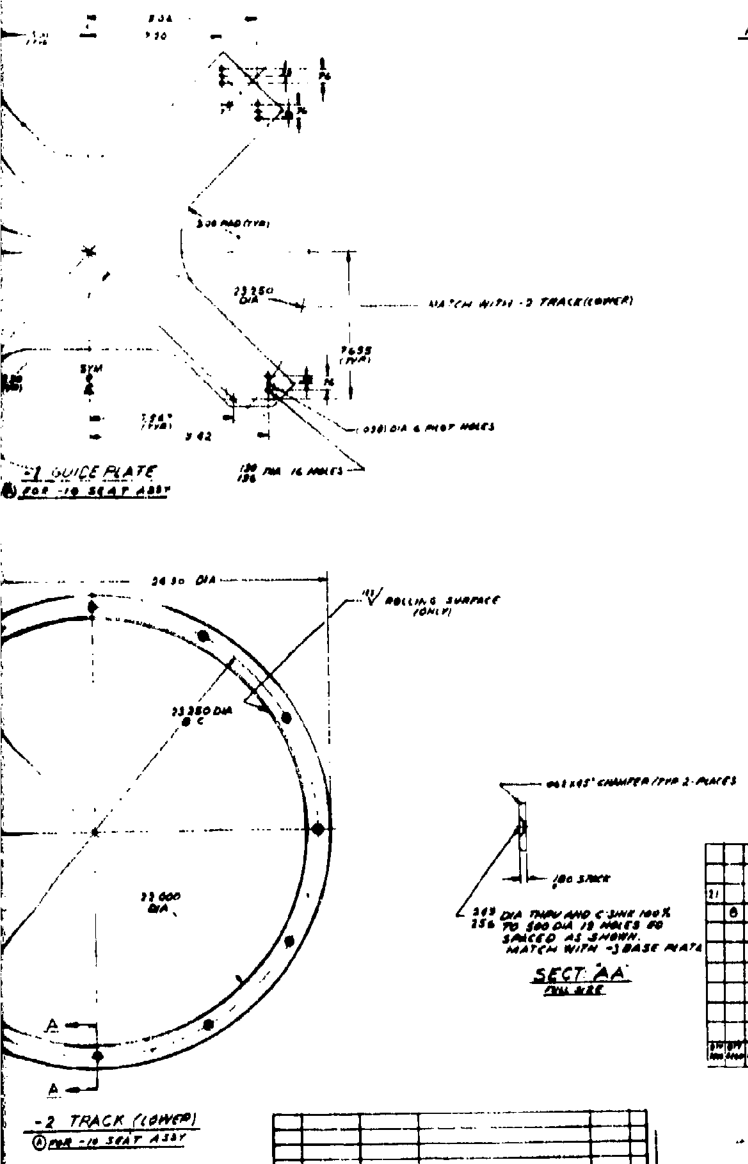

24.50 DIA
23.250 DIA B.C.
22.00 DIA
.263/.256 DIA 12 HOLES EQ SPACED AS SHOWN. MATCH WITH -2 TRACK
-3 BASE PLATE (TRACK)
Ⓐ FOR -10 SEAT ASSY
SYM
23.250 DIA
MATCH WITH -2 TRACK
.038 DIA 4 PILOT HOLES
.190/.156 DIA 16 HOLES
-1 GUIDE PLATE
Ⓐ FOR -10 SEAT ASSY
24.50 DIA
ROLLING SURFACE (ONLY)
23.250 DIA B.C.
23.000 DIA
A
A
-2 TRACK (LOWER)
Ⓐ FOR -10 SEAT ASSY
.038 DIA PILOT HOLE
-7 SADDLE
MAT'L FROM AND10137-1606
.263/.256 DIA THRU
.500 DIA STOCK
-8 SPACER

B

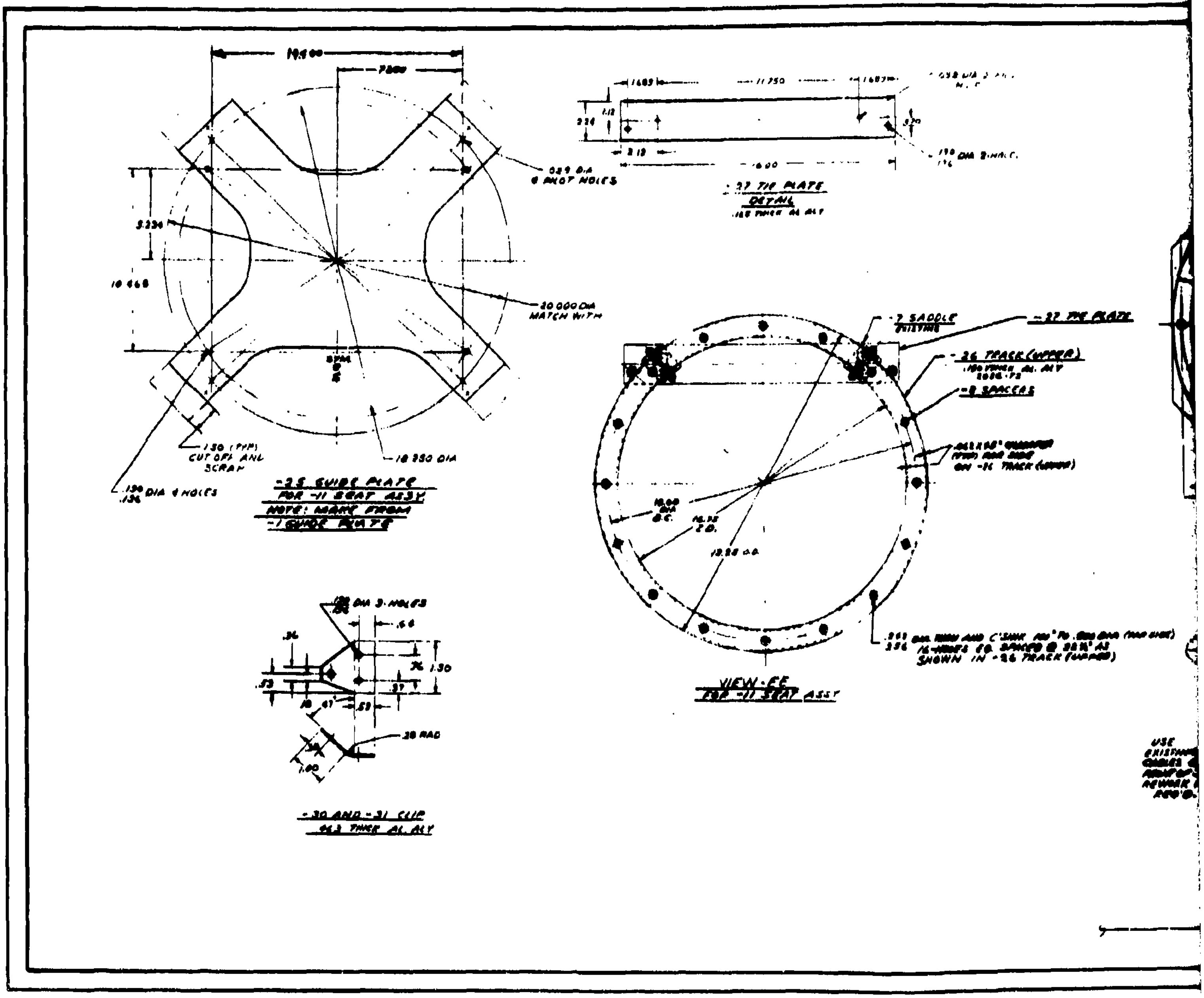


NOTES
1- BREAK ALL SHARP EDGES AND CORNERS

QTY	QTY	QTY	QTY	QTY	QTY	QTY	PART NO.	DESCRIPTION	MATERIAL
21							SK25067-8	SPACER	AL ALY
	6						-7	[illegible]	AL ALY
		1					-6	TIE PLATE	AL ALY
			1				-5	[illegible]	AL ALY
				1			-4	TRACK (UPPER)	AL ALY
					1		-3	[illegible]	AL ALY
						1	-2	TRACK (LOWER)	AL ALY
						1	SK25067-1	GUIDE PLATE	AL ALY

ENERGY ATTENUATING GUNNER SEAT MOCK-UP

SK-25067A



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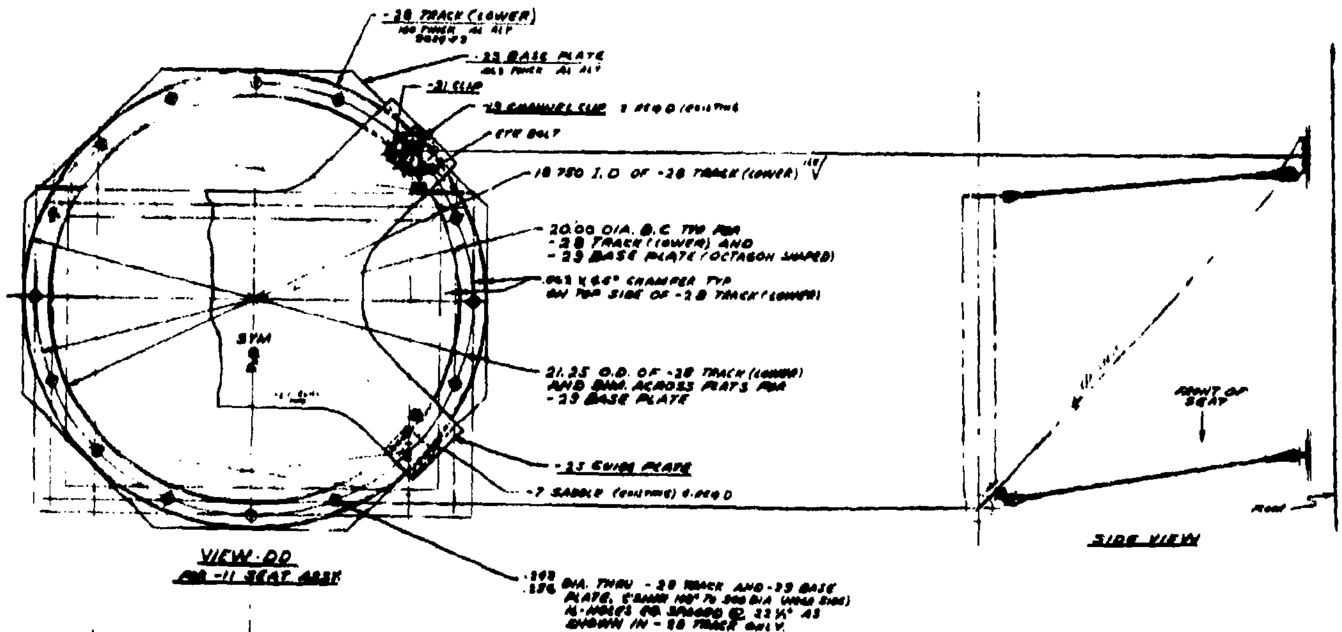

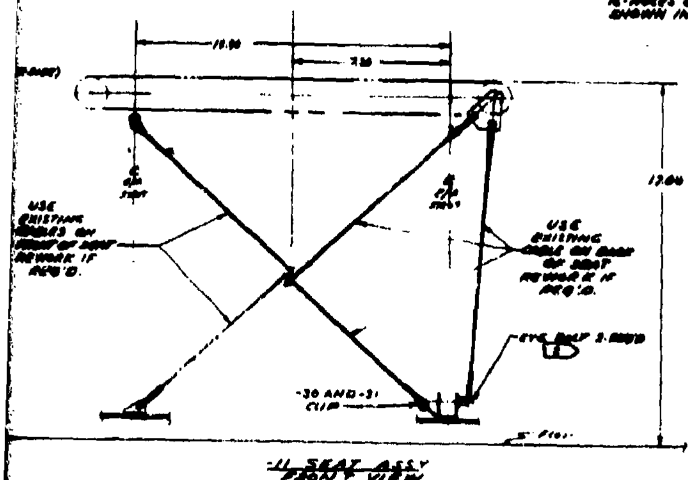

-31	CLIP	AL ALY
-30	CLIP	AL ALY
-23	BASE PLATE	AL ALY
-28	TRACK-(LOWER)	AL ALY
-27	TIE PLATE	AL ALY
-26	TRACK-(UPPER)	AL ALY
SK-25067-25	GUIDE PLATE	MADE FROM -1 GUIDE PLATE

PHILADELPHIA, PENNSYLVANIA

ENERGY ATTENUATING GUNNER SEAT MOCK-UP

SK-25067 A

B

CH-47 CRASHWORTHY GUNNER'S SEAT

The detail design drawings of the CH-47 crashworthy gunner's seat are presented on the following pages.

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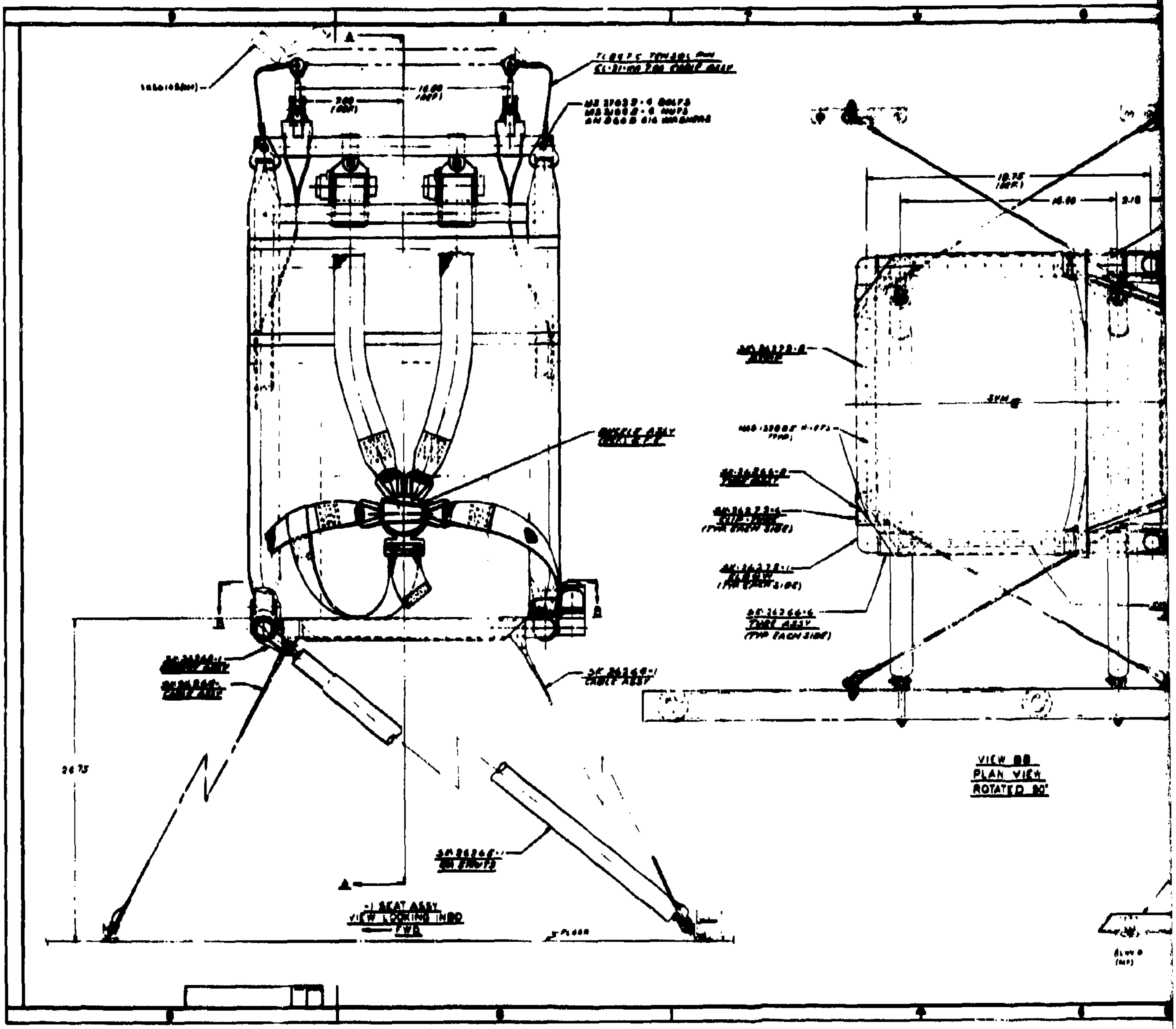

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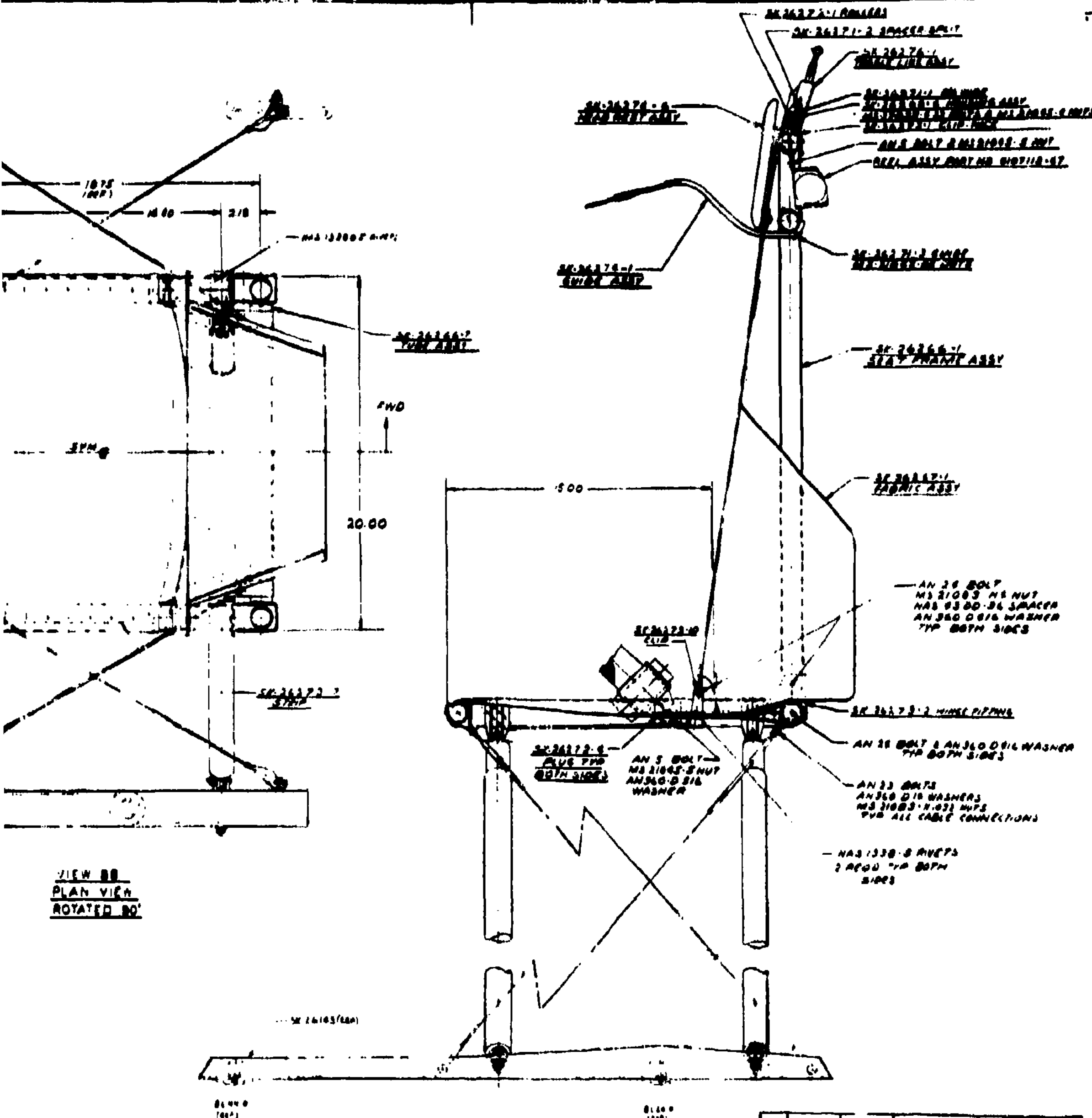
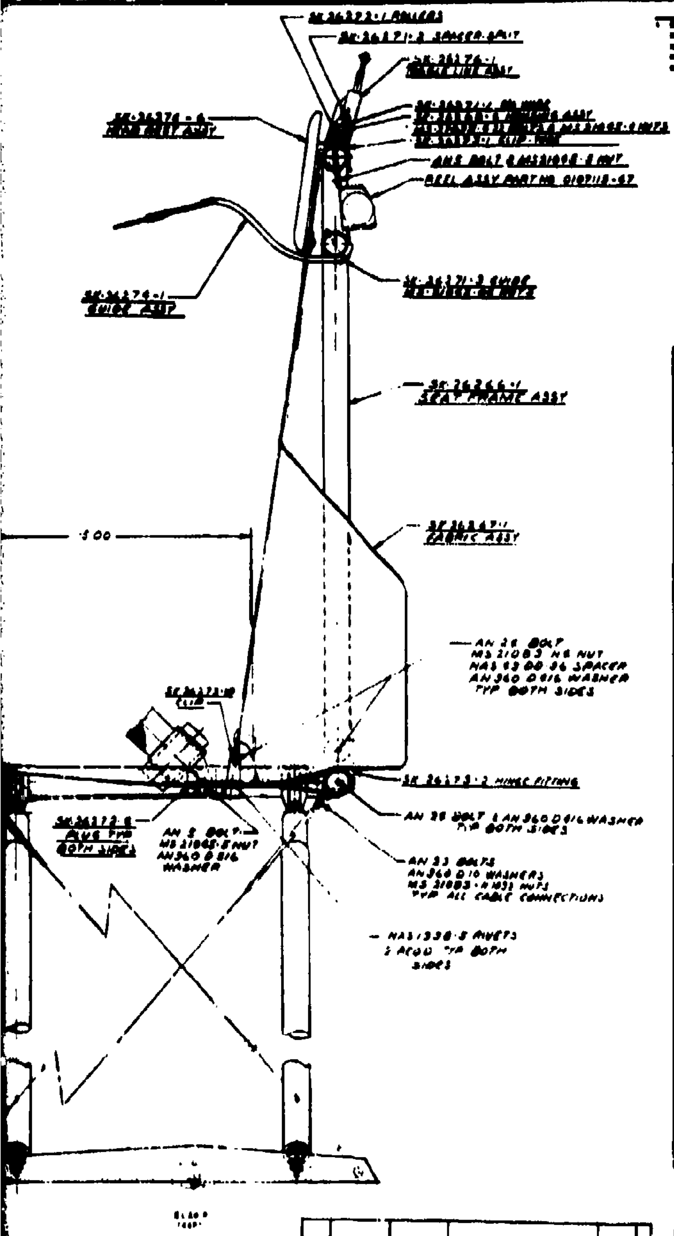


6	AN960D816	WASHER
12	AN960D616	WASHER
6	AN960D10	WASHER
81	NAS1338D5	RIVET
6	NAS43D0-36	SPACER
6	MS21042-5	NUT
6	MS21083-6	NUT
6	MS21083N6	NUT
6	MS21083N3	NUT
6	MS27033-6	BOLT
6	AN26	BOLT
6	AN 23	BOLT
6	AN 5	BOLT
2	CL-21-FA P00	CABLE ASSY
2	TL84PC	TENSION PIN
6	010118-67	REEL ASSY
2	SK26268-6	HOUSING ASSY
2	SK26268-1	BRACKET ASSY
1	SK26267-1	FABRIC ASSY
1	SK26266-8	TUBE ASSY
1	SK26266-7	TUBE ASSY
2	SK26266-6	TUBE ASSY
1	SK26266-1	SEAT FRAME ASSY
2	SK-26265-1	AN STRUT ASSY
6	SK26260-1	CABLE ASSY
1	SK-26274-6	HEAD REST ASSY
2	SK-26270-1	GUIDE ASSY
2	SK-26275-1	ELBOW
2	SK-26273-10	CLIP
1	SK-26273-8	STRIP
2	SK-26273-7	STRIP
2	SK-26273-6	CLIP TUBE
2	SK-26273-2	HINGE FITTING
2	SK-26273-1	CLIP-TUBE
2	SK-26273-6	PLUG
6	SK-26271-1	ROLLER
2	SK-26271-3	GUIDE
2	SK-26271-2	SPACER-SPLIT
2	SK-26271-1	G/A WIRE
2	SK-26276-1	TOGGLE ASSY
X	SK26182-1	SEAT ASSY

B



6	AN960D816L	WASHER
12	AN960D816	WASHER
8	AN960D10	WASHER
21	NAS1398D5	RIVET
6	NAS43DD-36	SPACER
6	MS21083-5	NUT
6	MS21083-6	NUT
6	MS21083N6	NUT
6	MS21083N3L	NUT
6	MS27039-6	BOLT
6	AN26	BOLT
6	AN23	BOLT
6	AN5	BOLT
2	CC-31-XA P06	CABLE ASSY
2	TL807C	TENSION PIN
6	6107113-67	REEL ASSY
2	SK26268-6	HOUSING ASSY
2	SK26268-1	BRACKET ASSY
1	SK26267-1	FABRIC ASSY
1	SK26266-8	TUBE ASSY
1	SK26266-7	TUBE ASSY
2	SK26266-6	TUBE ASSY
1	SK26266-1	SEAT FRAME ASSY
2	SK26265-1	[illegible] STRUT ASSY
6	SK26269-1	CABLE ASSY
1	SK26276-6	HEAD REST ASSY
2	SK26274-1	GUIDE ASSY
2	SK26275-1	ELBOW
2	SK26273-10	CLIP
1	SK26273-8	STRIP
2	SK26273-7	STRIP
2	SK26273-6	CLIP TUBE
2	SK26273-2	HINGE FITTING
2	SK26273-1	CLIP-TUBE
2	SK26272-6	PLUG
6	SK26272-1	ROLLER
2	SK26271-3	GUIDE
2	SK26271-2	SPACER-SPLIT
2	SK26271-1	[illegible] HINGE
2	SK26276-1	TOGGLE ASSY
X	SK26102-1	SEAT ASSY

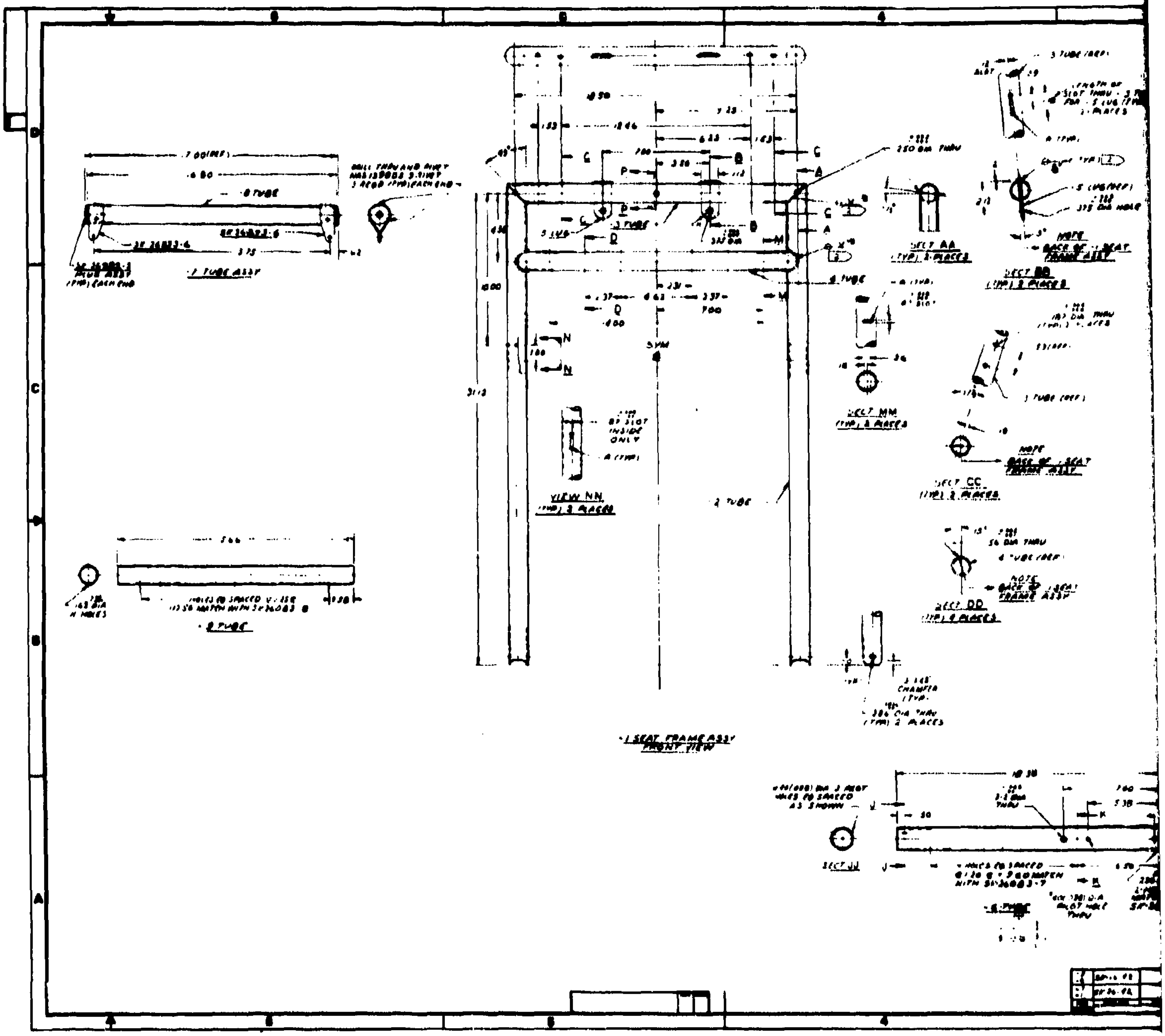
CRASHWORTHY GUNNER SEAT ASSEMBLY & INSTALL

CH-47

J 77272 SK26142

SK-26142

C



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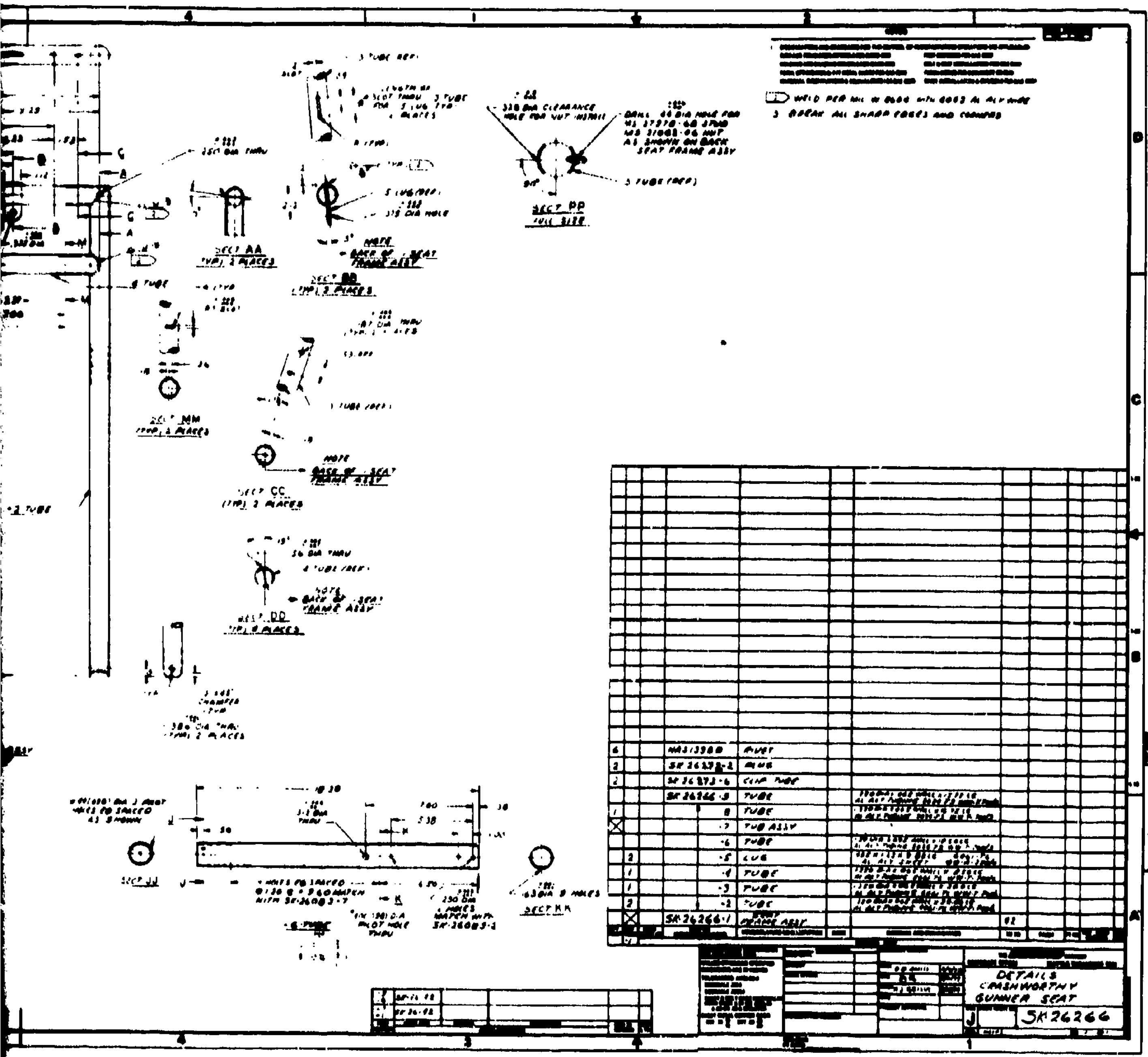
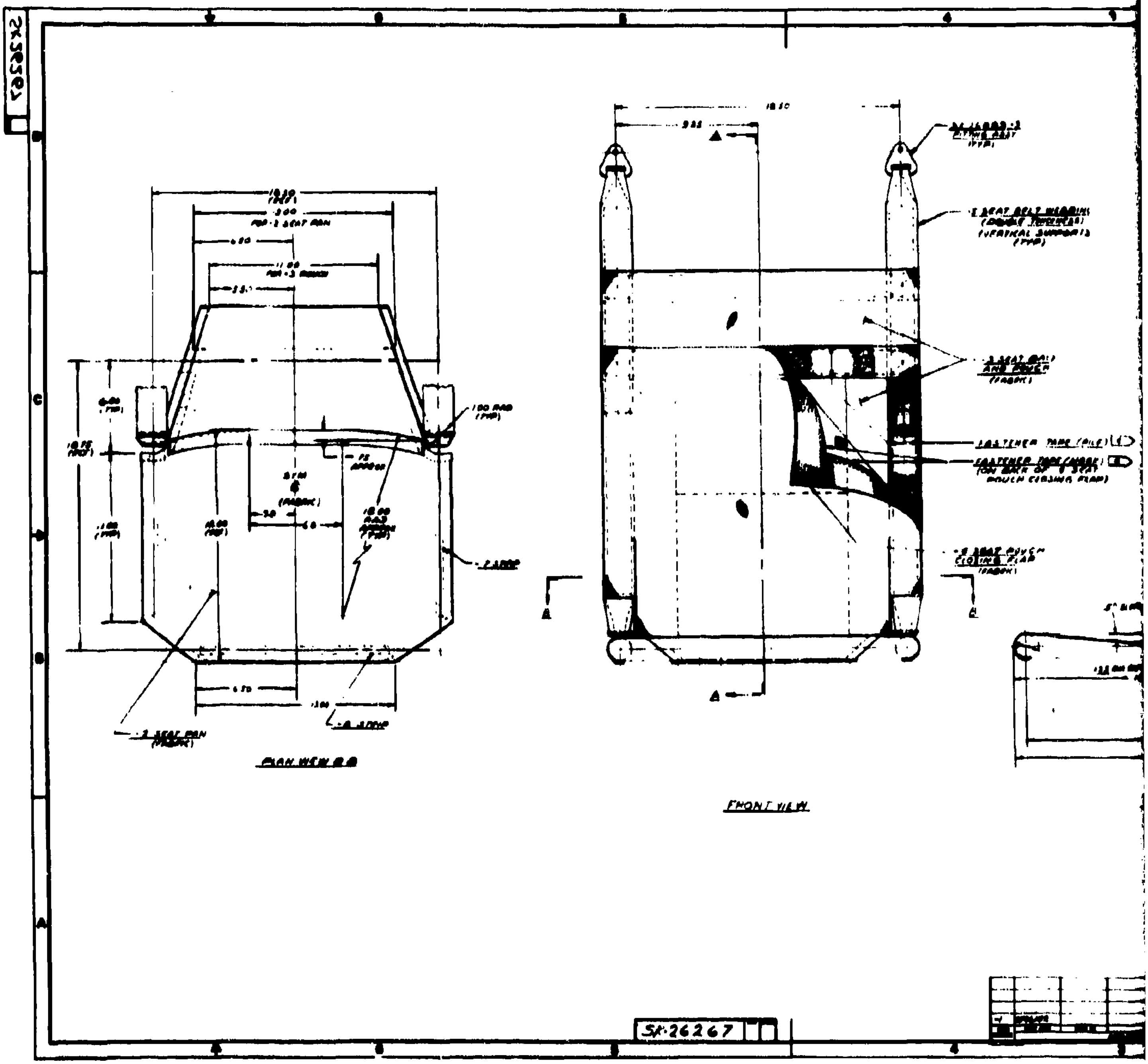


SECT PP
FULL SIZE
SECT AA
SECT BB
SECT MM
SECT CC
SECT DD
SECT JJ
SECT KK
NAS1398D RIVET
SK 26273-2 RING
SK 26273-6 CLIP TUBE
SK 26266-9 TUBE
-8 TUBE
-7 TUB ASSY
-6 TUBE
-5 LUG
-4 TUBE
-3 TUBE
-2 TUBE
SK 26266-1 SEAT FRAME ASSY
DETAILS
CRASHWORTHY
GUNNER SEAT
J
SK 26266

B



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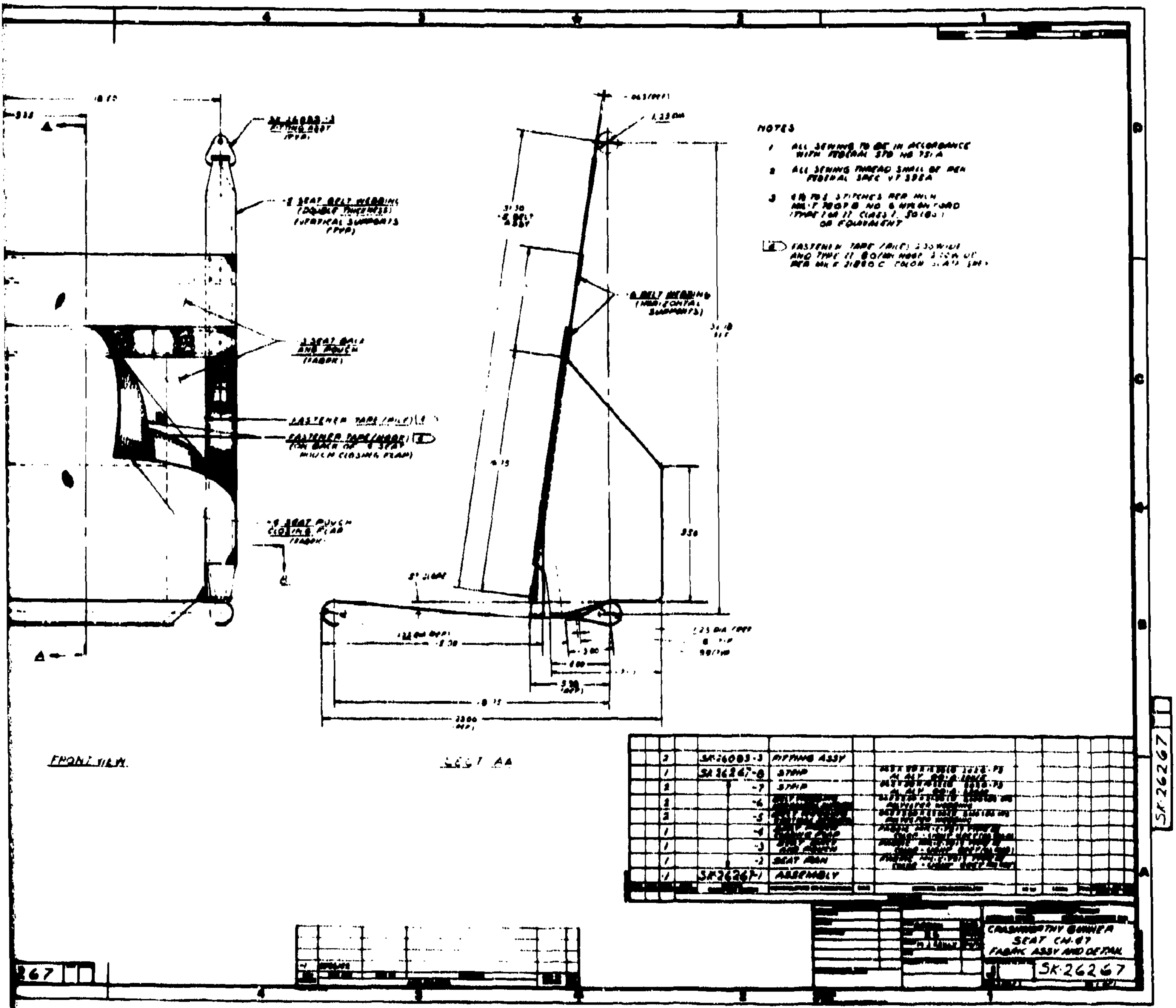
NOTES
1 ALL SEWING TO BE IN ACCORDANCE WITH FEDERAL STD NO 751 A
2 ALL SEWING THREAD SHALL BE PER FEDERAL SPEC V-T-295A
FRONT VIEW
SECT AA
SK-26083-3 FITTING ASSY
SK 26267-8 STRAP
-7 STRAP
-2 SEAT PAN
SK26267-1 ASSEMBLY
CRASHWORTHY GUNNER SEAT CM-67
FABRIC ASSY AND DETAIL
SK-26267

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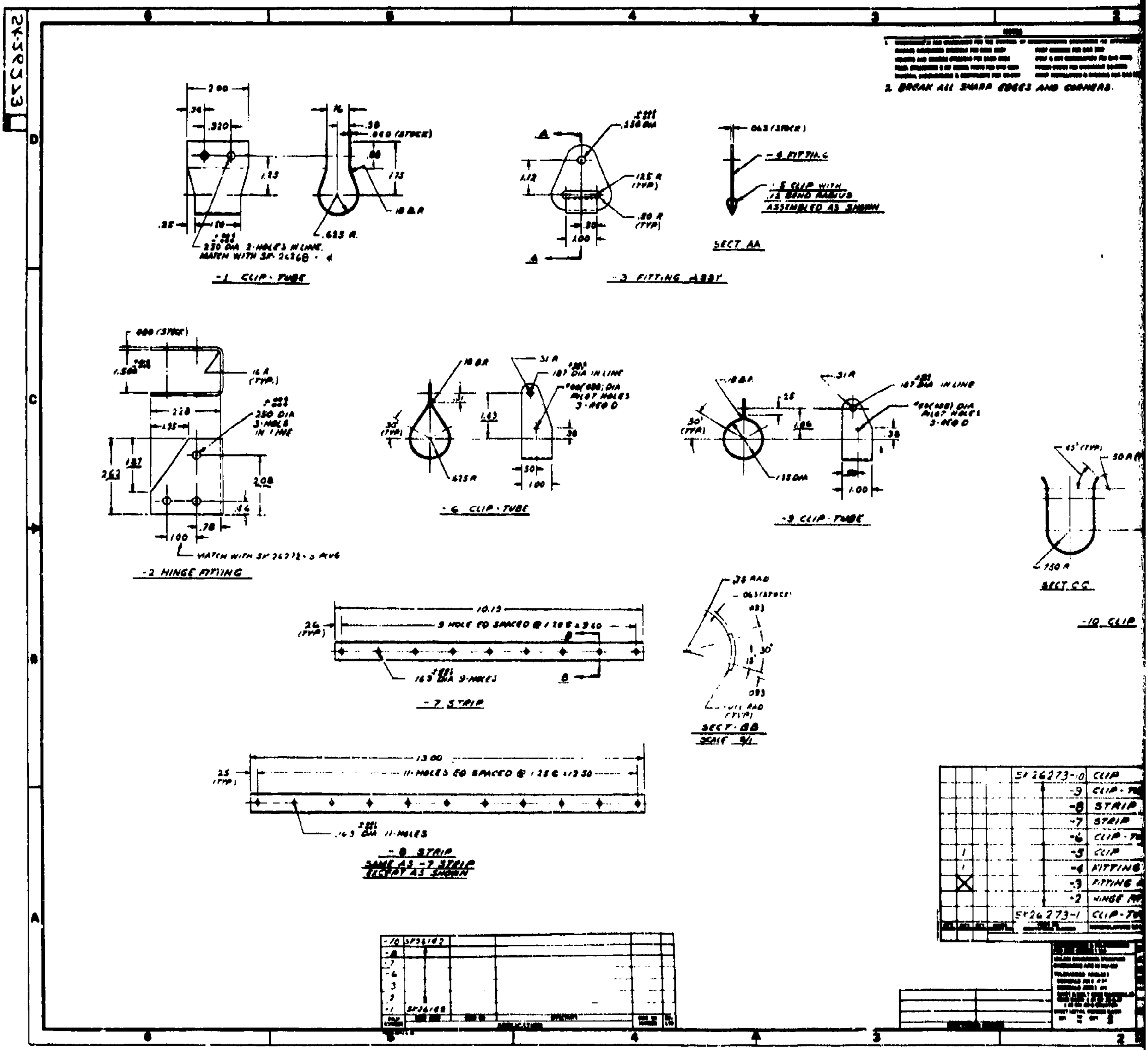

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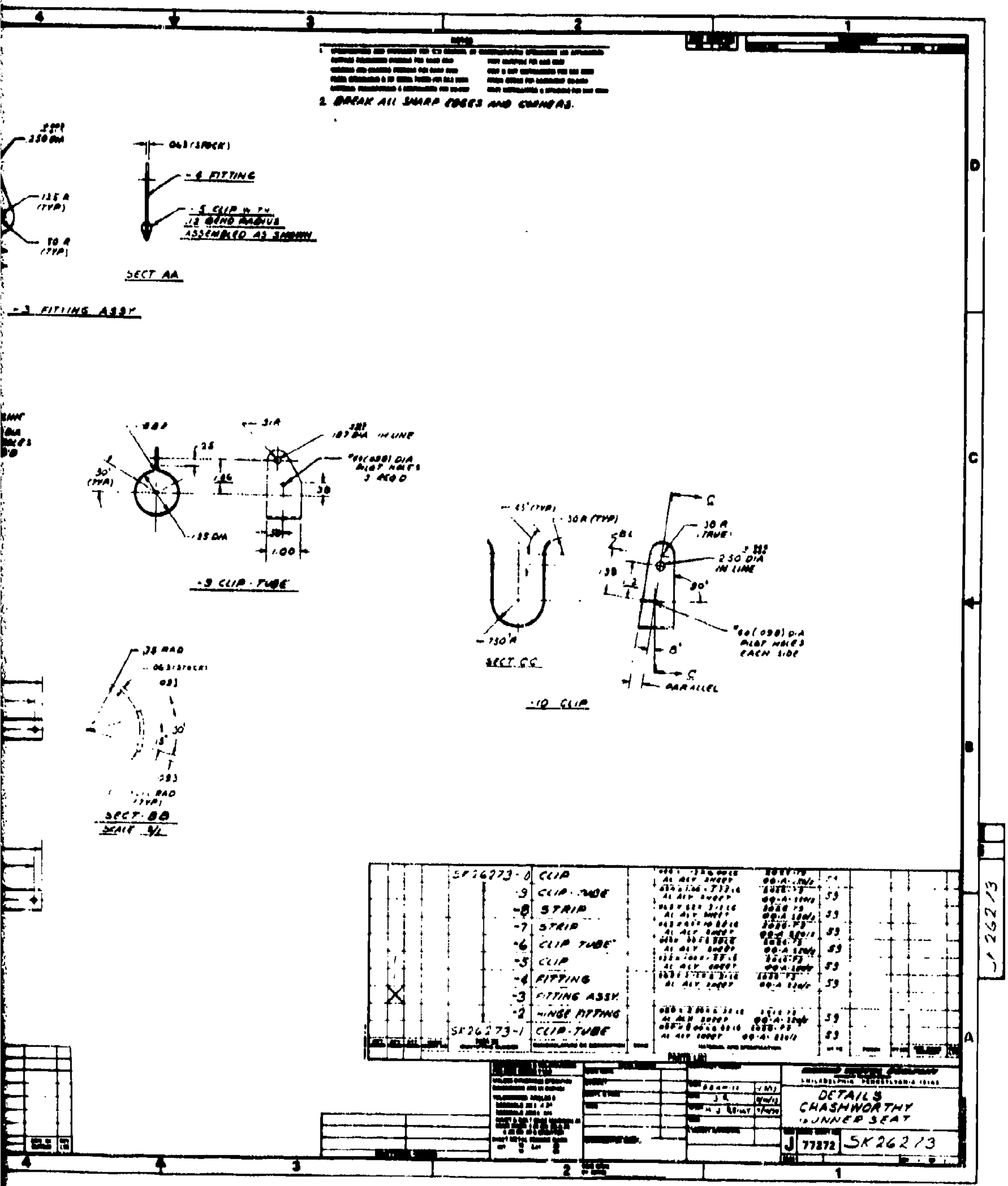

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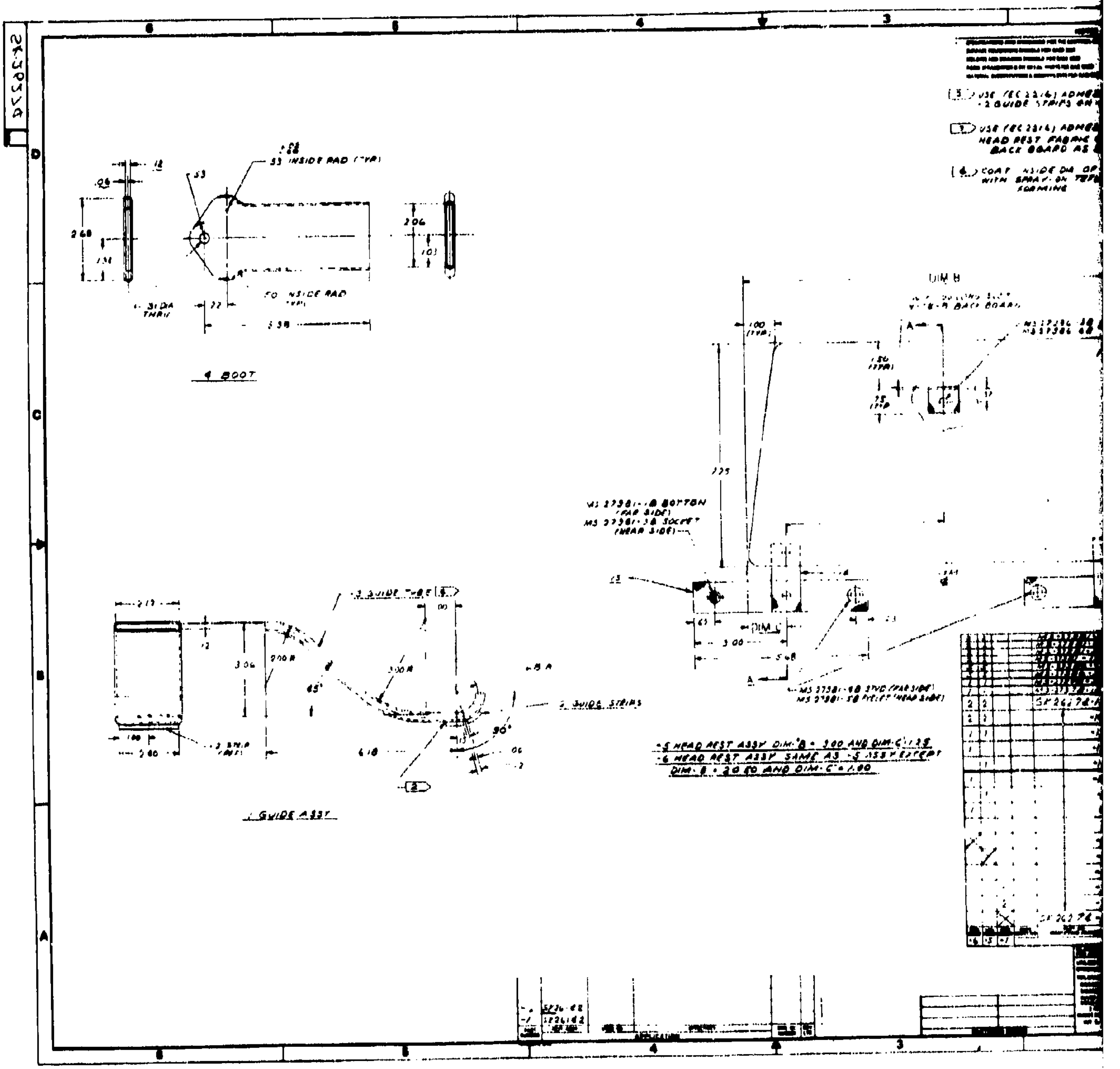

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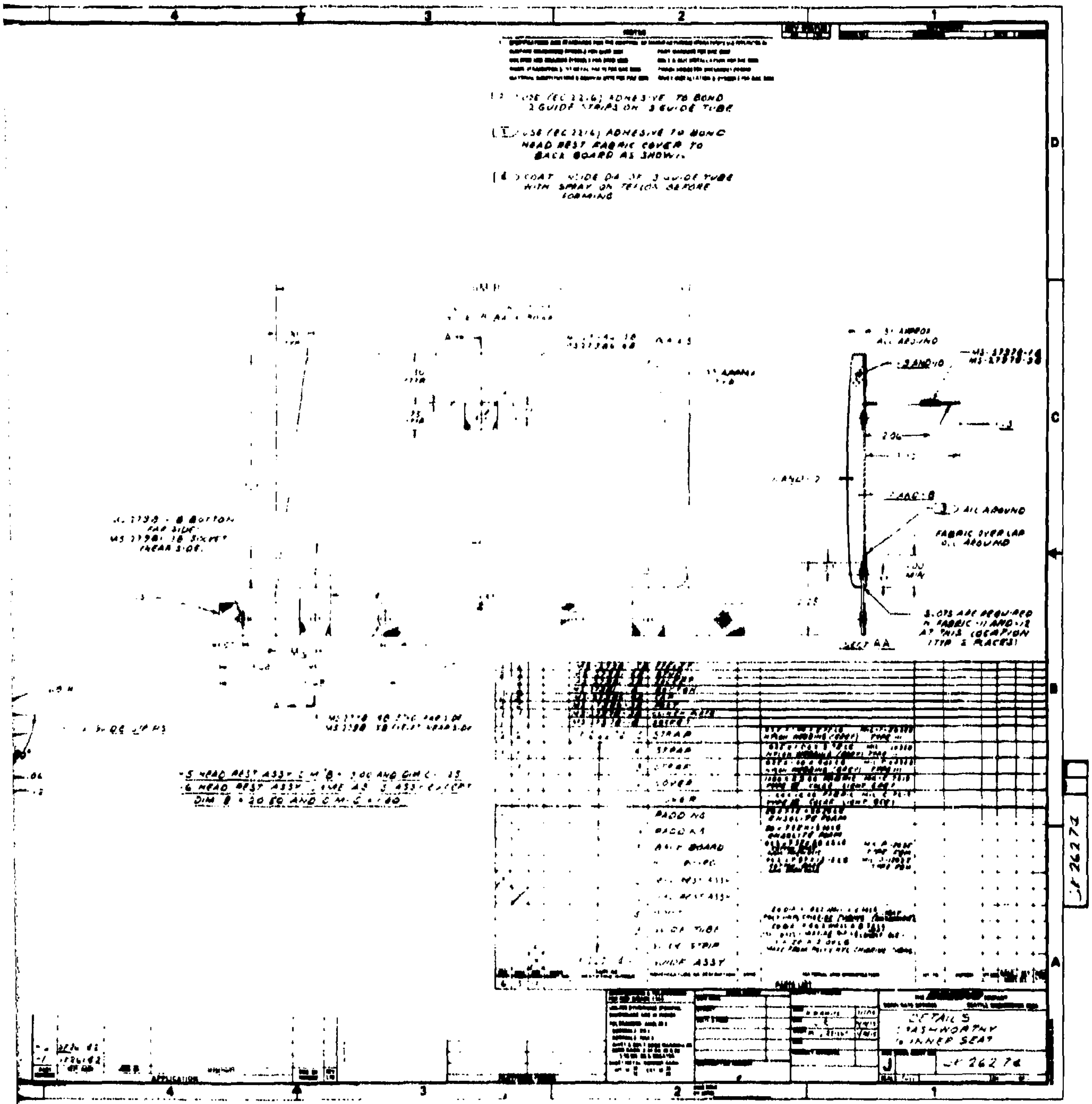

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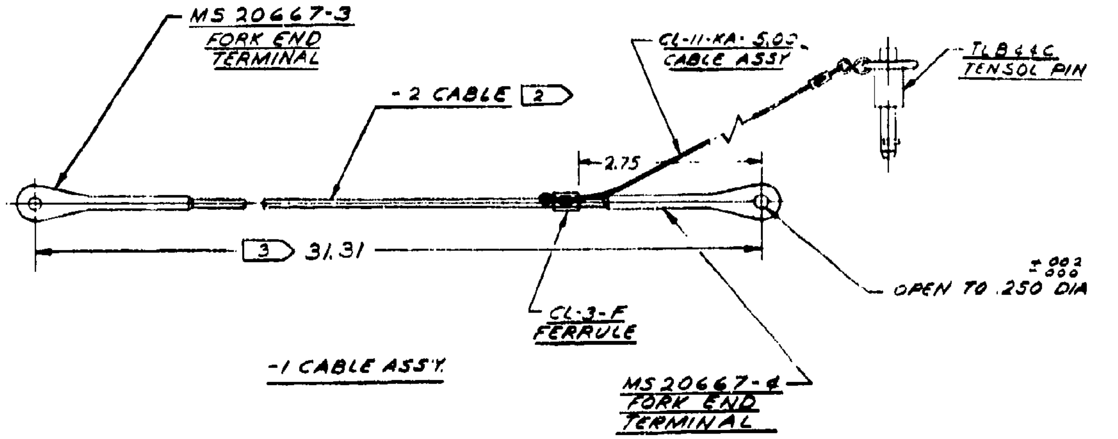
β

NOTES

2 SWAGE -2 CABLE (...
USE OF MS 20667-...

3 DIMENSION IS WITH...

4 -2 CABLE SHALL B...
ELONGATION ENE...



	1		CL-3-F	FER...
	1		CL-11-KA-5.00	CAB...
	1		TL844C	TEN...
	1		MS20667-4	FOR... WIRE...
	1		MS20667-3	FOR... WIRE...
	AS REQD		-2	CA...
	X		SK-26264-1	CA...
	-1			

PART NUMBER	NEXT ASSY	USED ON	EFFECTIVITY	REV LTR
-1	SK-26182			

APPLICATION

FASTENER CODES

A

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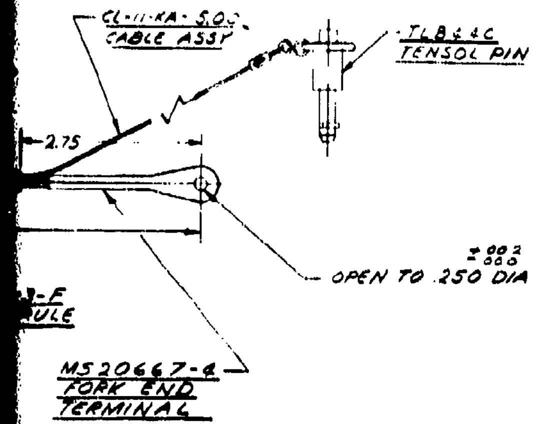
NOTES:

2 SWAGE -2 CABLE (ONE END) TO FACILITATE USE OF MS20667-3 FORK END TERMINAL.

3 DIMENSION IS WITH CABLE TAUT UNDER 10 LB. LOAD.

4 -2 CABLE SHALL BE ANNEALED TO PRODUCE HIGH ELONGATION ENERGY ATTENUATION FEATURES.



1		CL-3-F	FERRULE	CARR LANE MFG CO 4200 CARR LANE COURT ST. LOUIS, MO.		
1		CL-11 KA-500	CABLE ASSY.	CARR LANE MFG. CO. 4200 CARR LANE COURT ST. LOUIS, MO.		
1		TLB44C	TENSOL PIN	NORCO INC. P.O. BOX 405 GEORGETOWN CONN.		
1		MS20667-4	FORK END WIRE ROPE TERMINAL			
1		MS20667-3	FORK END WIRE ROPE TERMINAL			
AR		-2	CABLE	1/8 DIA. (7X19 SS) WIRE ROPE MIL-C-5424	4	
X		SK-26264-1	CABLE ASSY			
QTY REQD		PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION		

PARTS LIST

BOEING VERTOL COMPANY
PHILADELPHIA PENNSYLVANIA 19142

DRN D. DAMICO 6/10/74
CHK R 6/12/74
ENGR M. J. REILLY 6/10/74

CABLE ASSYS. CRASHWORTHY GUNNER SEAT

D 77272 SK-26264

SCALE NONE

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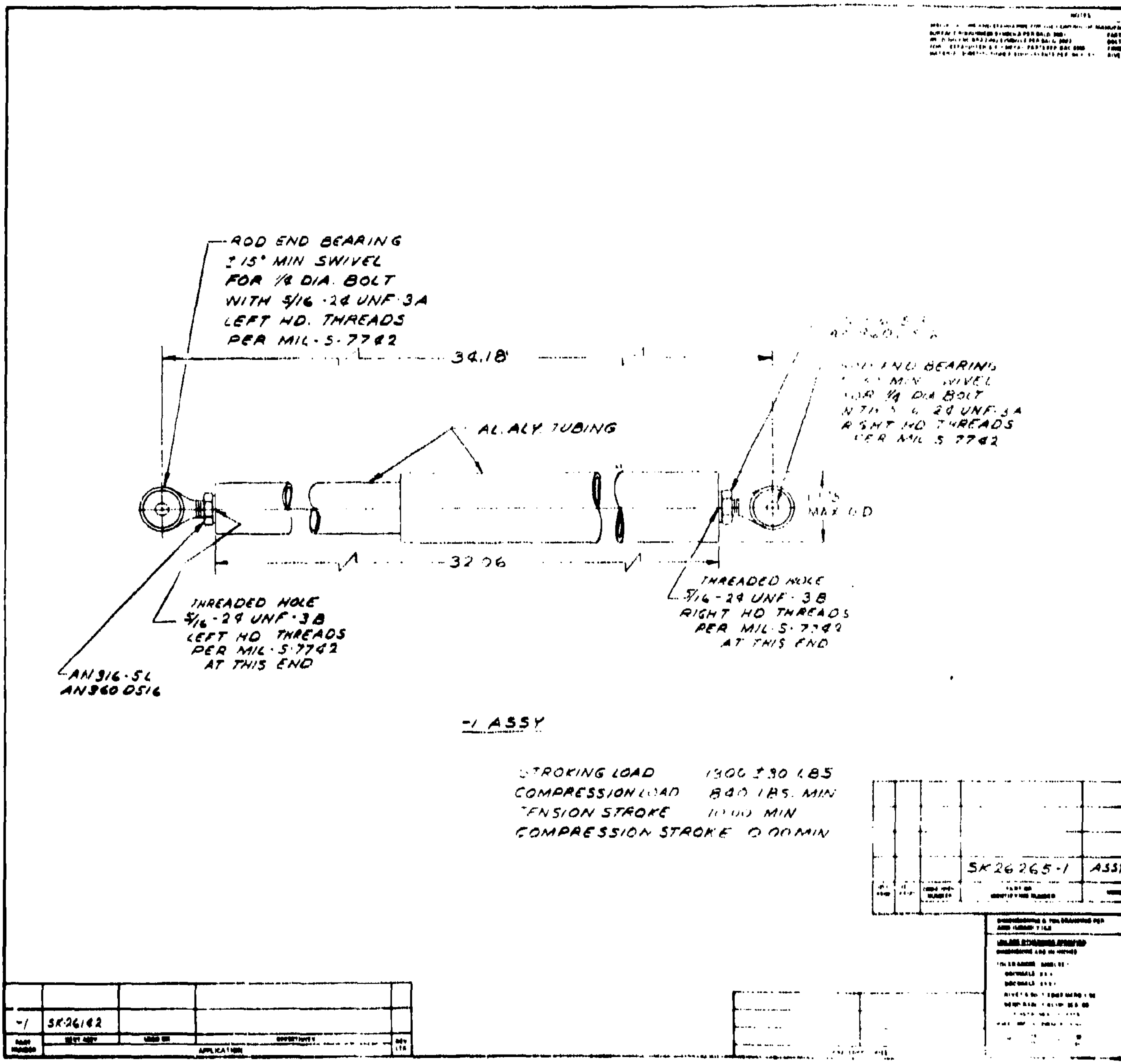
B



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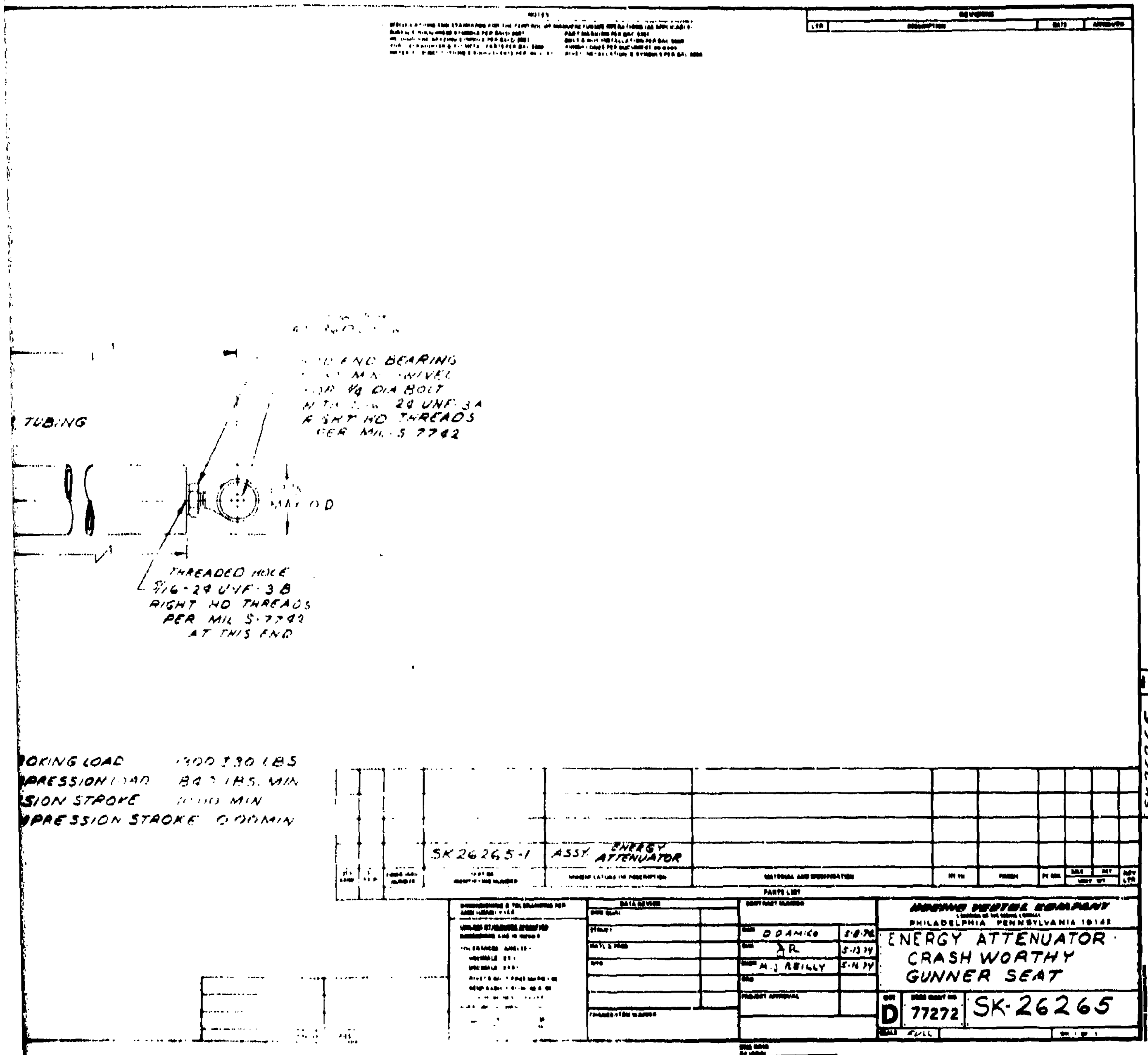

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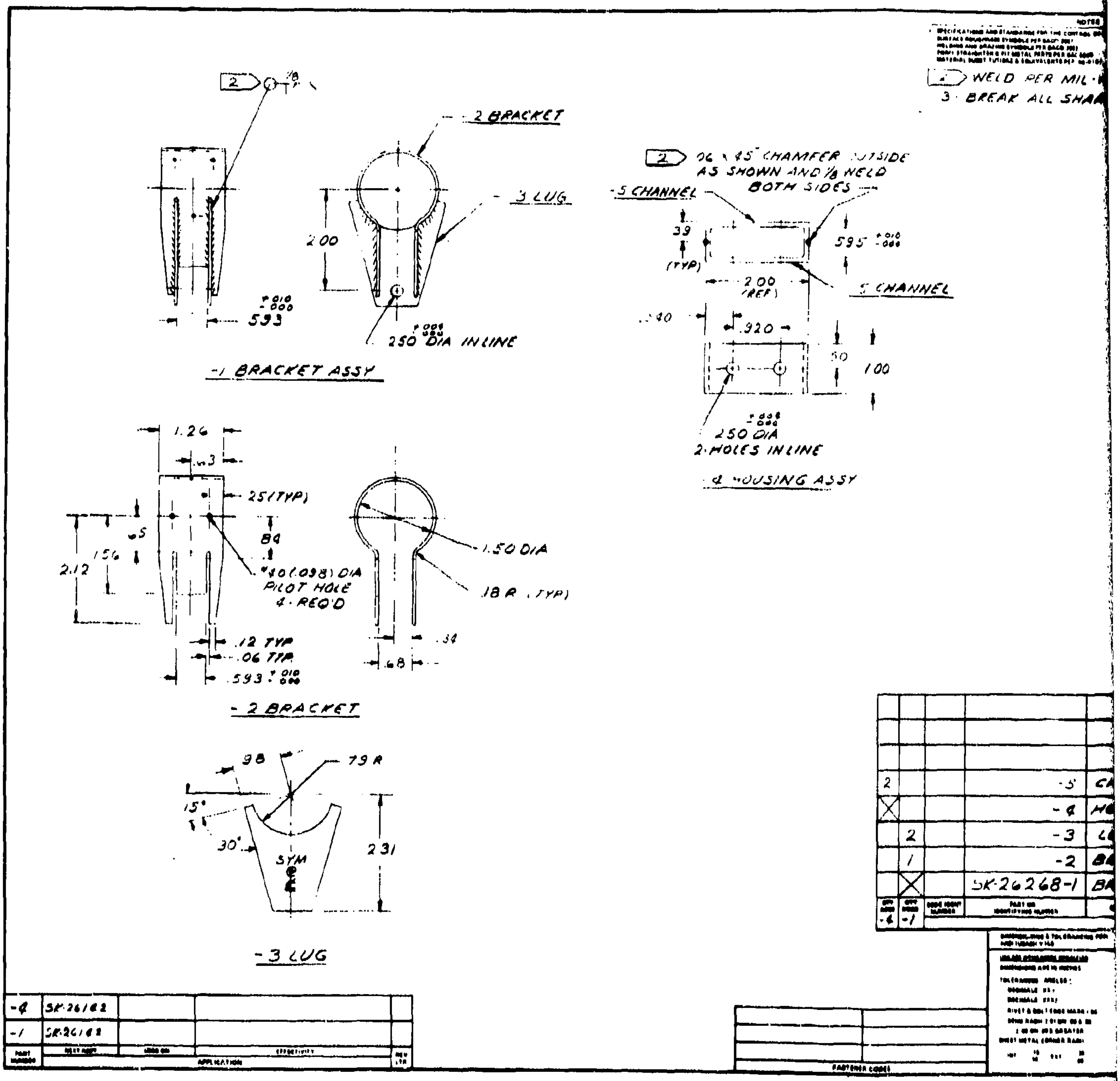

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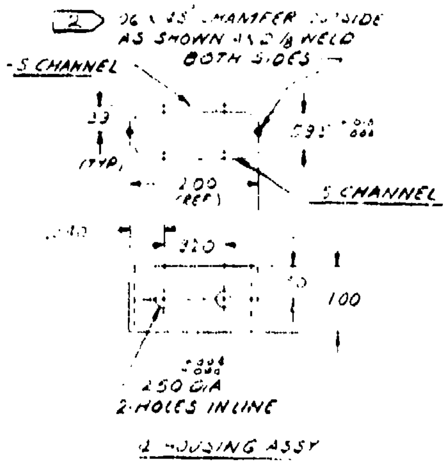
NOTES

2. WELD PER MIL-W-8604 WITH 4043 ALUM WIRE
3. BREAK ALL SHARP EDGES AND CORNERS



2			-5	CHANNEL	MAKE FROM AND 10137 2001 X 1.1166 6061-T6 AL ALY EXTR QQ-A-200/8	
X			-4	HOUSING ASSY		42
	2		-3	LUG	.063 X 2.68 X 2.5016 6061-T6 AL ALY SHEET QQ-A-250/11	
	1		-2	BRACKET	.063 X 1.250 X 7.3816 6061-T6 AL ALY SHEET QQ-A-250/11	
	X		SK-26268-1	BRACKET ASSY		42
QTY REQD -4	QTY REQD -1	CODE IDENT NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION	

PARTS LIST

BOEING VERTOL COMPANY
PHILADELPHIA PENNSYLVANIA 19142

DRAWN DOMMICK 5/8/74
CHK J.R. 5/13/74
ENGR M. J. REILLY 5/10/74

DETAILS
CRASHWORTHY GUNNER SEAT CH-47

D 77272 SK-26268

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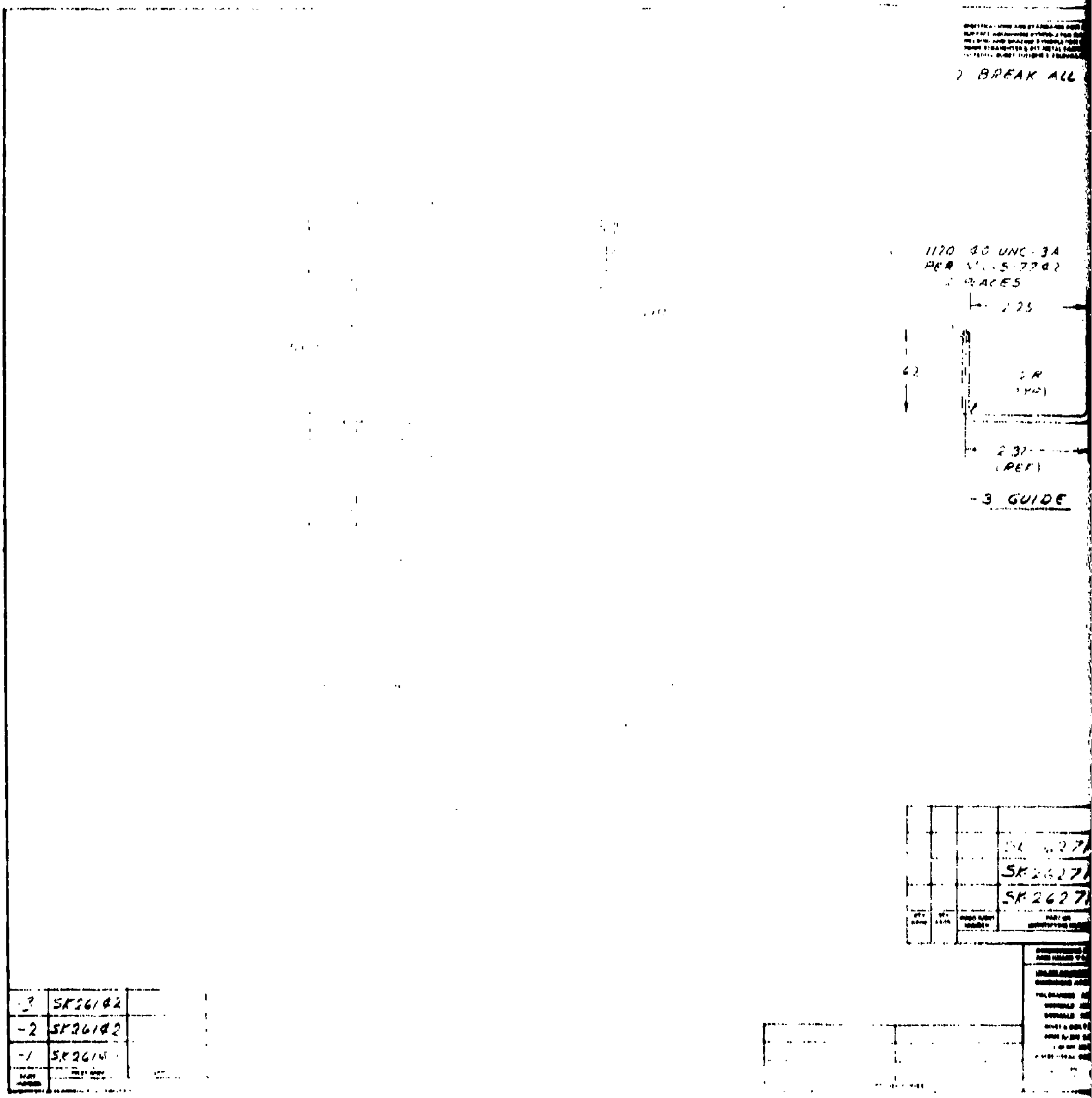

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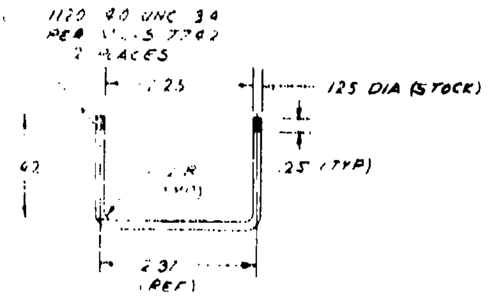
2 BREAK ALL SHARP EDGES AND CORNERS.



-3 GUIDE

			SK 26271-3	GUIDE	.55 DIA X 5.50 LG 4130 STL ROD MIL-S-6758	.150
			SK 26271-2	SPACER SPLIT	.250 O.D. X .063 WALL X .80 LG 5052-0 AL ALY TUBING WW-T-700/4	35
			SK 26271-1	WIRE E/A	.110 DIA. X 46.0 LG MUSIC WIRE SPRING STL. QQ-W-470	NONE

PARTS LIST

PHILADELPHIA PENNSYLVANIA 19142

D. D'AMATO 4/6/73

J R 4/10/74

M J REILLY 4/10/74

DETAILS
CRASHWORTHY
GUNNER SEAT

D 77272 SK-26271

SK-26271

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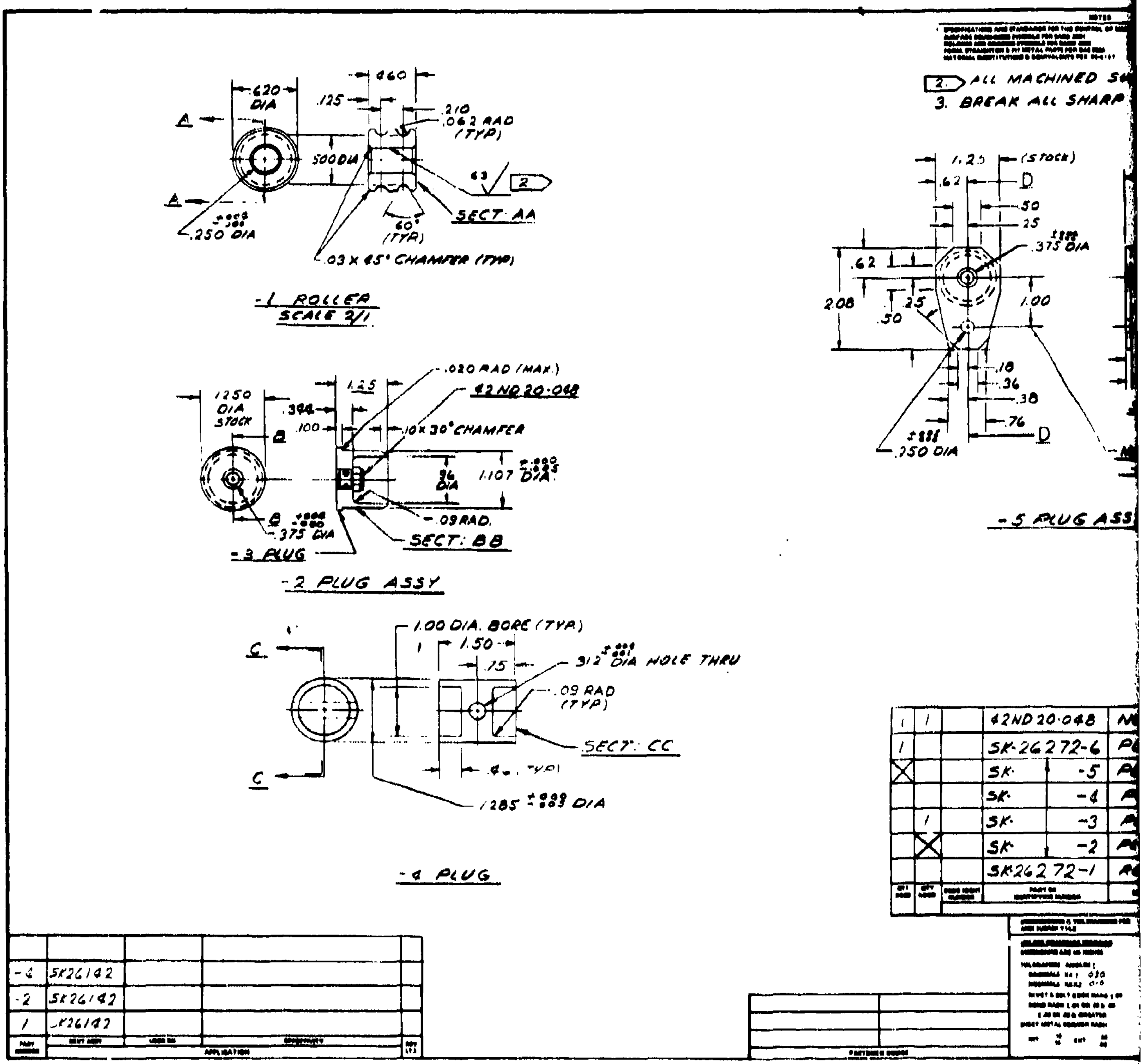
B



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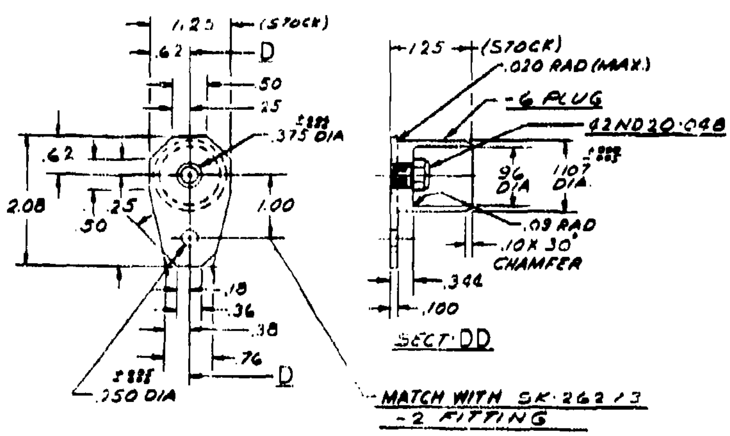
NOTES

2. ALL MACHINED SURFACES FINISH 125 EXCEPT AS NOTED
3. BREAK ALL SHARP EDGES AND CORNERS.



-5 PLUG ASSY

DIA HOLE THRU

C-CC

QTY REQD	QTY REQD	CODE IDENT NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION							
1	1		42ND20-048	NUT-SPLINE	ELASTIC STOP NUT CORP. UNION NEW JERSEY.							
1			SK-26272-6	PLUG	1.25 X 1.25 X 2.10 LG 2024-T4 AL. ALY. SQ. BAR QQ-A-225/6							
X			SK -5	PLUG ASSY								
			SK -4	PLUG	1.375 DIA. X 1.625 LG 2024-T4 AL. ALY. RD. BAR QQ-A-225/6							
	1		SK -3	PLUG	1.250 DIA. X 1.125 LG. 2024-T4 AL. ALY. RD. BAR QQ-A-225/6							
	X		SK -2	PLUG ASSY								
			SK-26272-1	ROLLER	.625 DIA. X .60 LG. 4130 STL. RD. BAR MIL-S-6758	150						

PARTS LIST

BOEING VERTOL COMPANY
PHILADELPHIA PENNSYLVANIA 19142

DRAWN: D D'AMICO 4/4/73
CHECK: J R 4/10/73
ENGR: H J REILLY 4/10/73

DETAILS
CRASHWORTHY
GUNNER SEAT

SIZE D | CODE IDENT NO. 77272 | SK-26272

TOLERANCES: DECIMALS .XX ± .030, .XXX ± .010

FASTENER CODES

B

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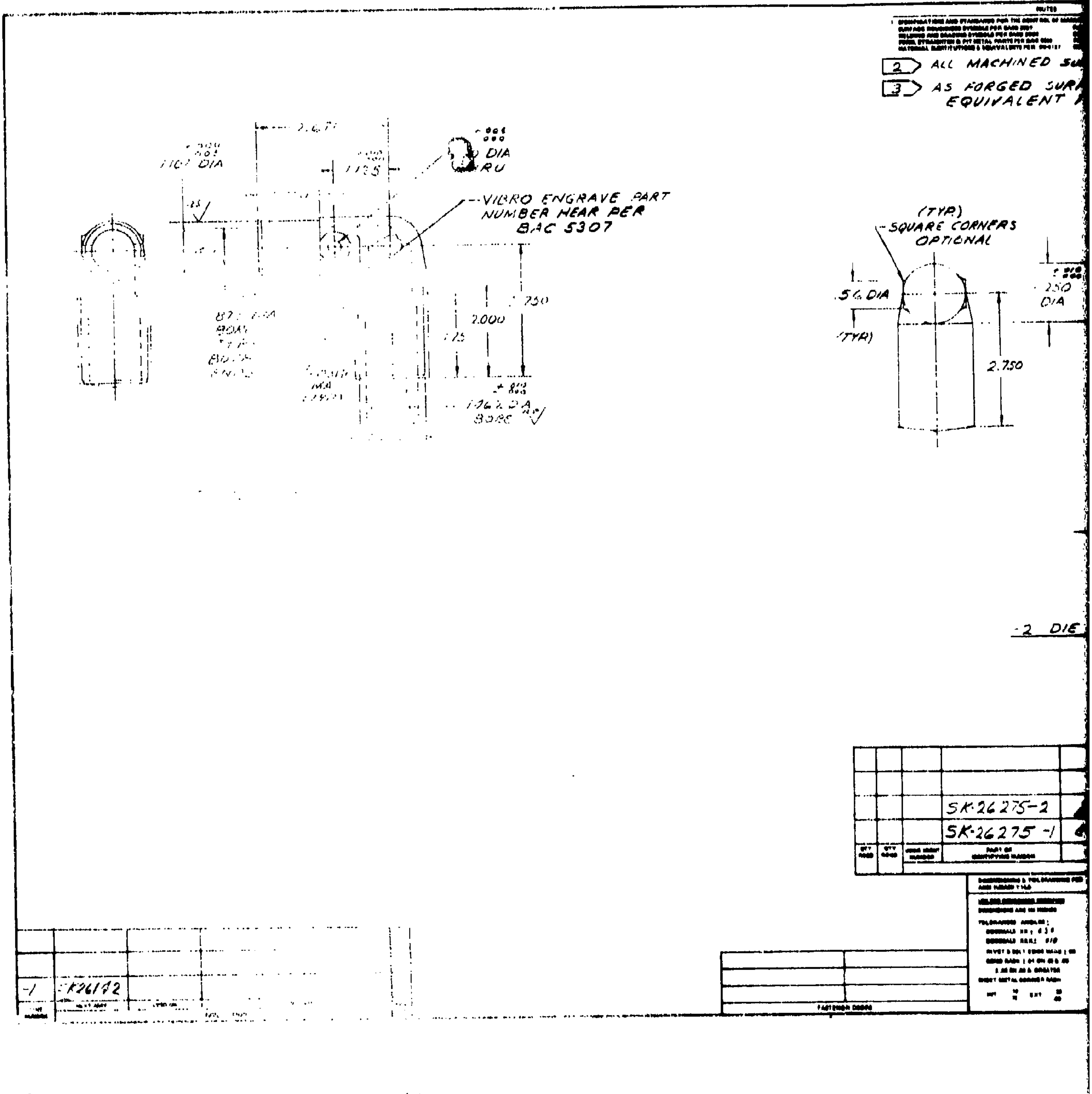

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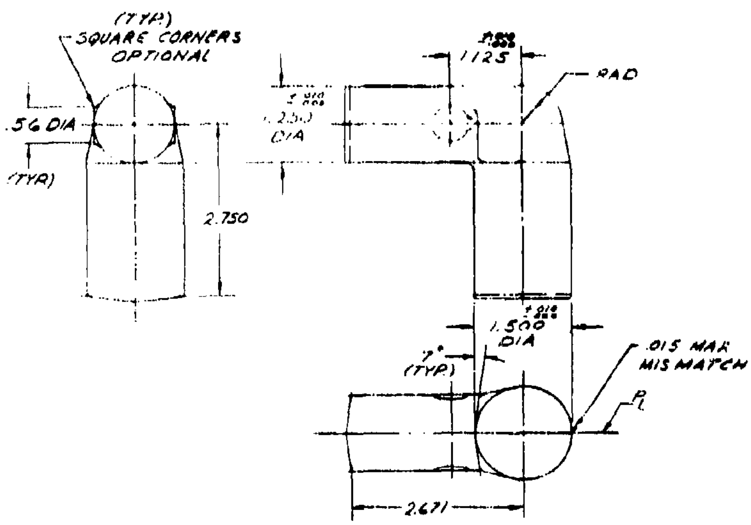
NOTES

2 ALL MACHINED SURFACES FINISH 125√

3 AS FORGED SURFACES 250√ VISUALL EQUIVALENT TO.

RO ENGRAVE PART
BER NEAR PER
BAC 5307



-2 DIE FORGING 3

			SK-26275-2	ELBOW DIE FORGING	AL ALY 2014-T6 FORGING QQ-A-367 COMP 2014 TEMPT6	65							
			SK-26275 -1	ELBOW	MAKE FROM -2								
QTY REQD	QTY REQD	CODE IDENT NUMBER	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	MATERIAL AND SPECIFICATION								

PARTS LIST

BOEING VERTOL COMPANY
PHILADELPHIA PENNSYLVANIA 19142

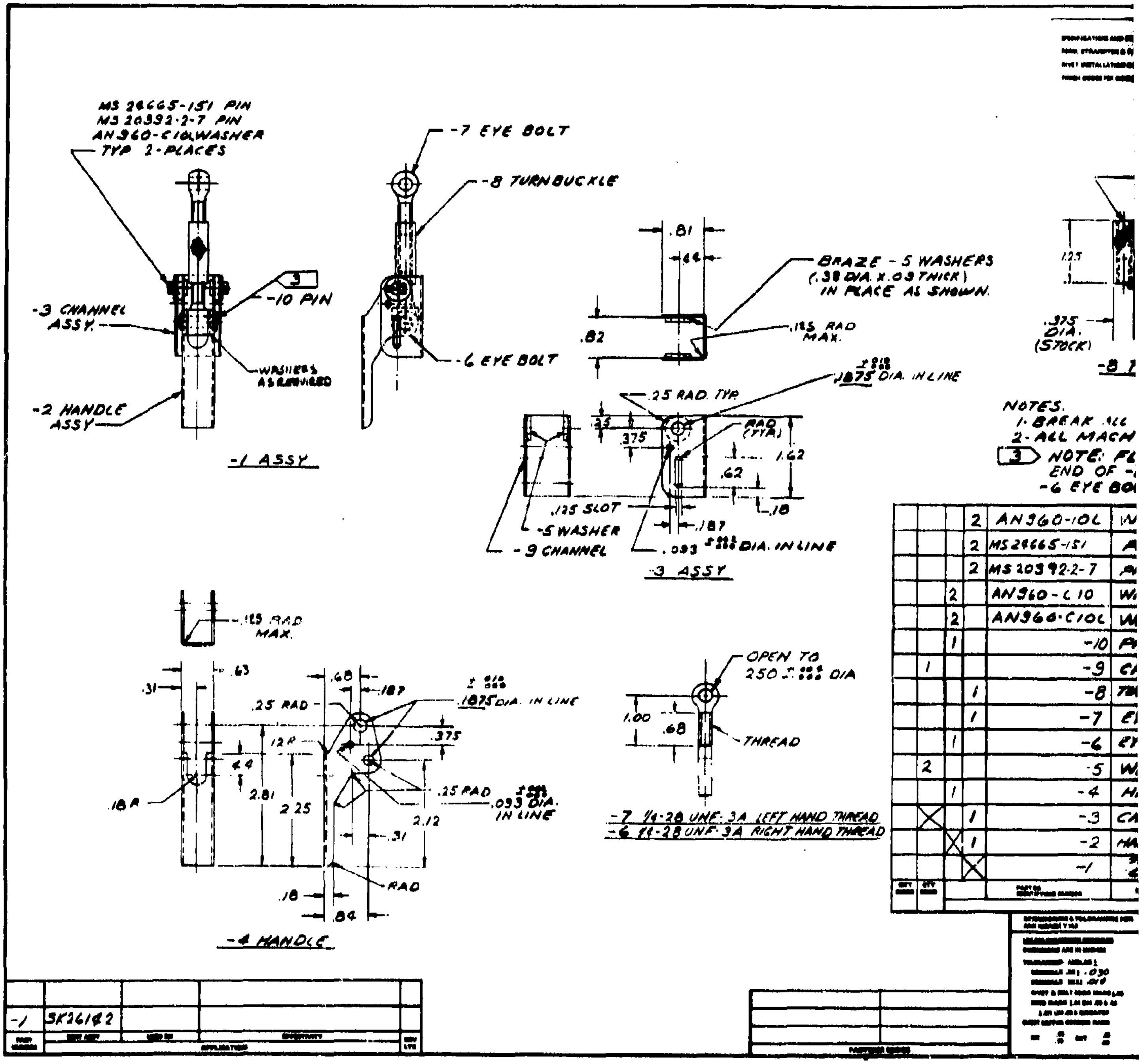
D.D'AMICO
J R
J REILLY

ELBOW DETAIL
CRASHWORTHY
GUNNER SEAT

D 77272 SK-26275

SK-26275

FASTENER CODES



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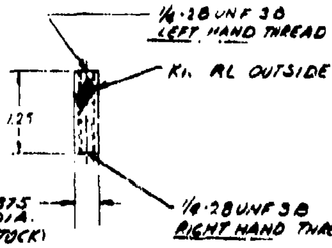
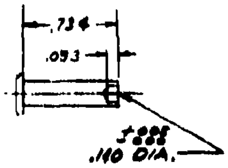


-8 TURNBUCKLE TUBE



-10 PIN
SIZE 2/1

-5 WASHERS
(.09 THICK)
CE AS SHOWN

DIA. NLINE

NOTES
1. BREAK ALL SHARP EDGES AND CORNERS
2. ALL MACHINED SURFACE FINISH 125
3 NOTE: FLARE OPEN AND PEEN LIGHTLY END OF -10 PIN AT ASSY WITH -2 HANDLE. -6 EYE BOLT MUST ROTATE FREE WITHOUT BINDING.

			2	AN960-10L	WASHER	
			2	MS24665-151	PIN	
			2	MS20392-2-7	PIN	
		2		AN960-C10	WASHER	
		2		AN960-C10L	WASHER	
		1		-10	PIN	MAKE FROM MS20392-2C27
	1			-9	CHANNEL	.040 x 1 5/8 x 2 7/8 LG. 4130 STL. SHT MIL-S-18729
			1	-8	TURNBUCKLE TUBE	.375 DIA x 1 3/8 LG. 4130 STL. BAR MIL-S-6758
			1	-7	EYE BOLT LEFT HAND	MAKE FROM CC-25-LO EYE BOLT CARR LANE MANUF CO. ST. LOUIS MO.
		1		-6	EYE BOLT RIGHT HAND	MAKE FROM CC-25-RO EYE BOLT CARR LANE MANUF CO ST. LOUIS MO.
	2			5	WASHER	.375 DIA. x .09 THICK 4130 STL BAR MIL-S-6758
		1		-4	HANDLE	.040 x 2 3/4 x 3 1/2 LG. 4130 STL. SHT. MIL-S-18729
	X		1	-3	CHANNEL ASSY.	
		X	1	-2	HANDLE ASSY.	
			X	-1	TOGGLE LINK ASSY.	

PARTS LIST

D.D'AMICO	7/3/73	
	7-16-73	TOGGLE LINK ASSY.
M.J. REILLY	7-20-73	CRASHWORTHY GUNNER SEAT
	7-20-73	D SK-26276

SK-26276

B

AIRCRAFT STRUCTURAL MODIFICATION DRAWING

The following drawing shows the modifications to the CH-47 structure that are necessary for installation of the crash-worthy gunner's seat.

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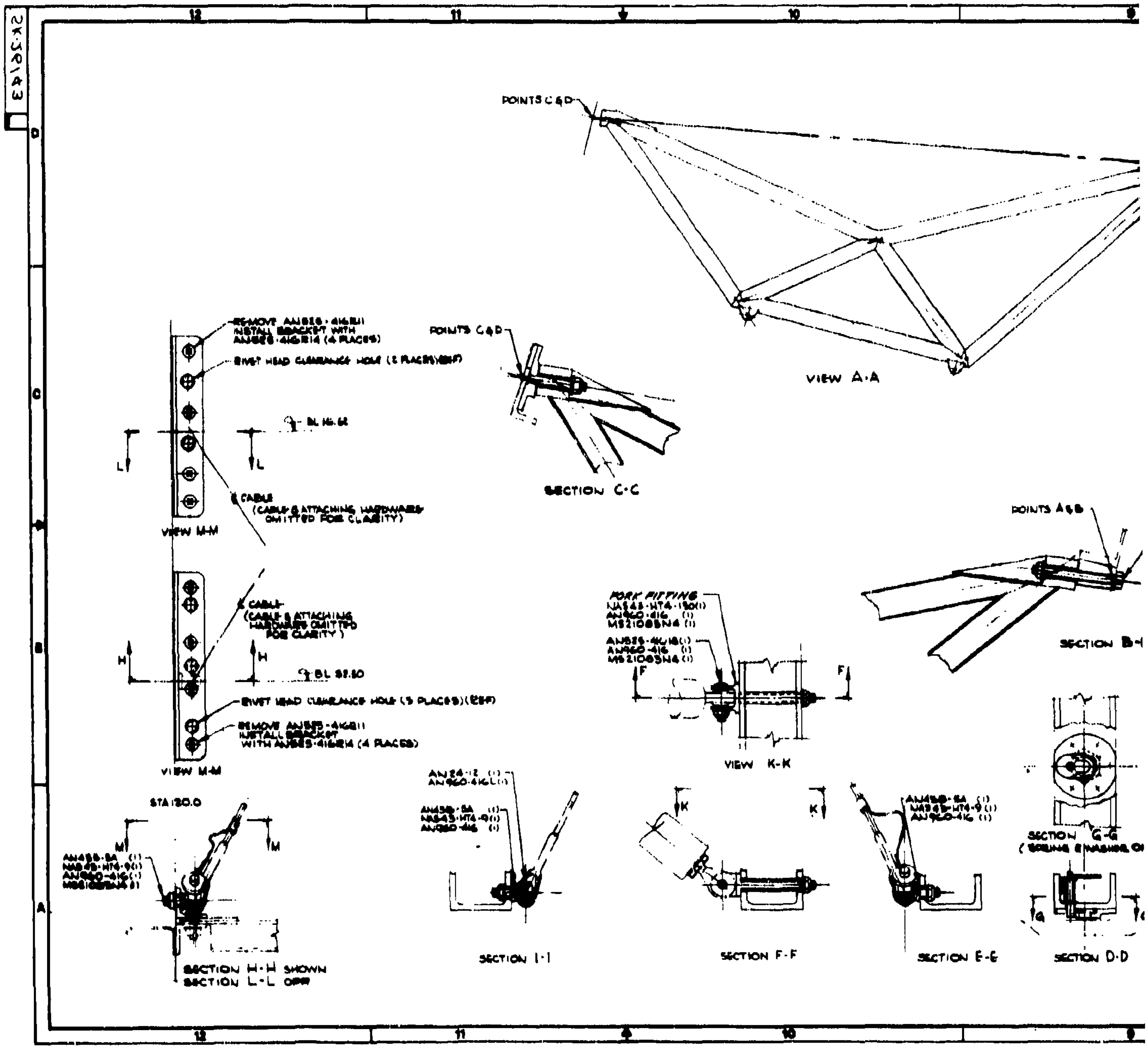

A

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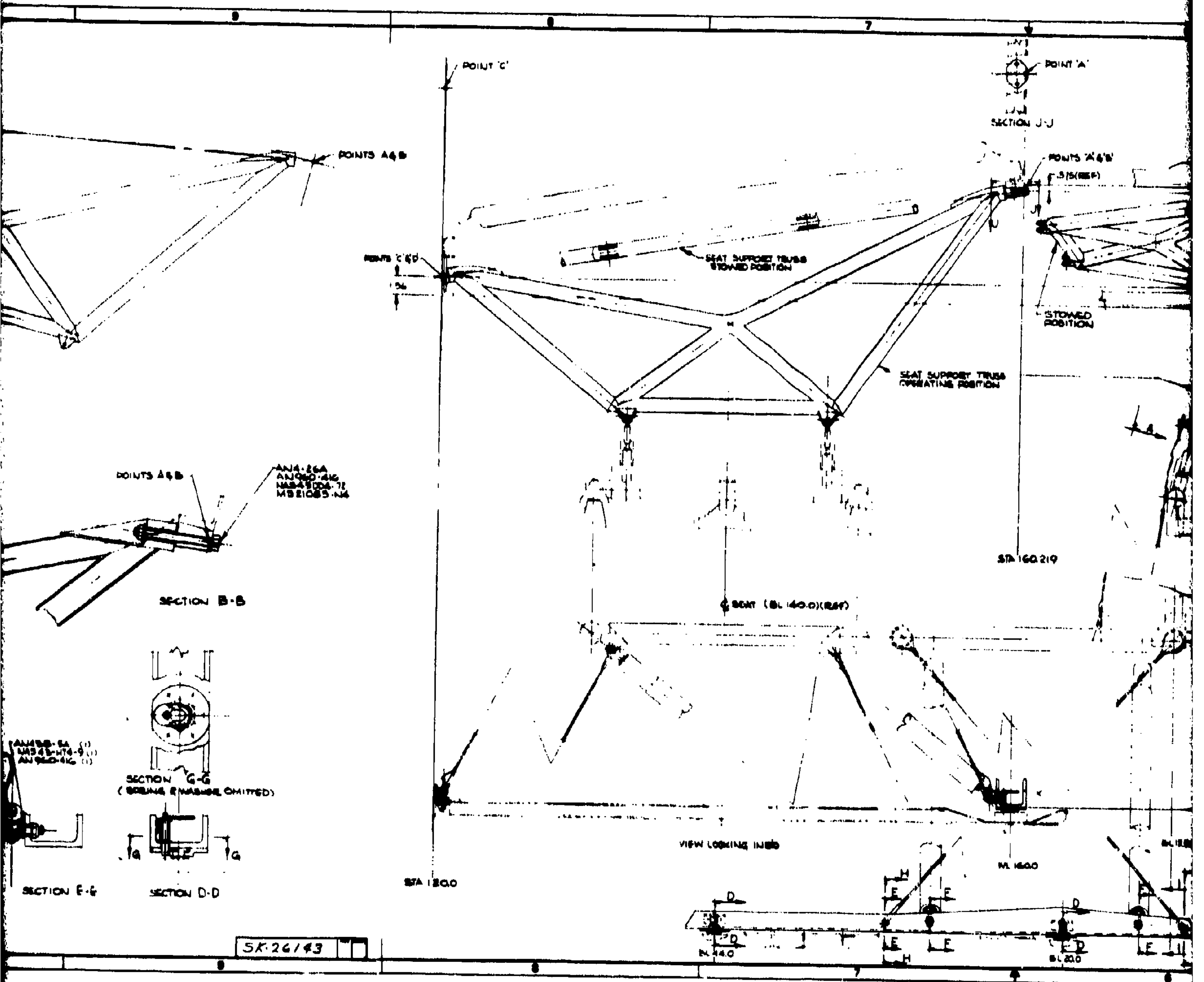
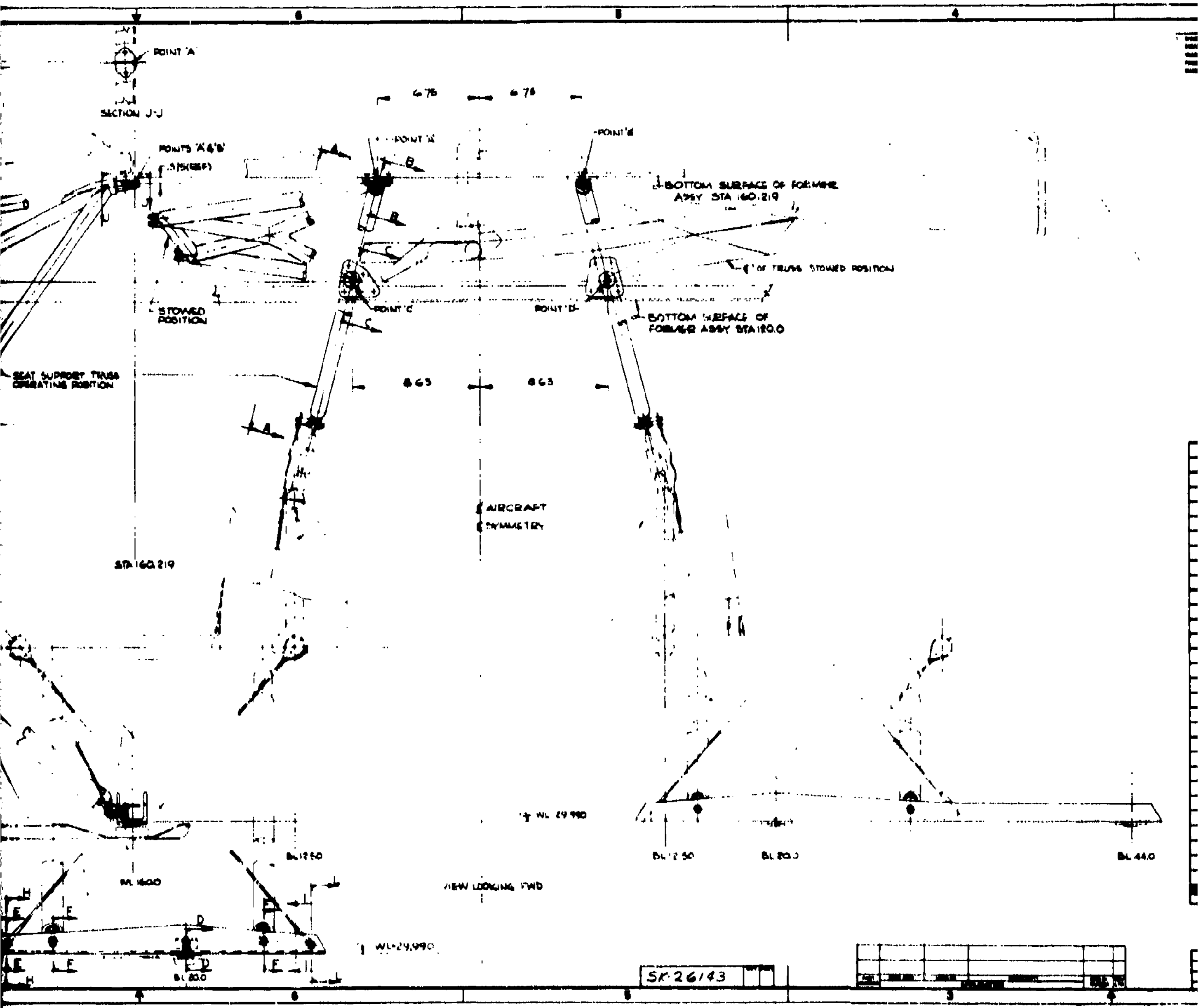
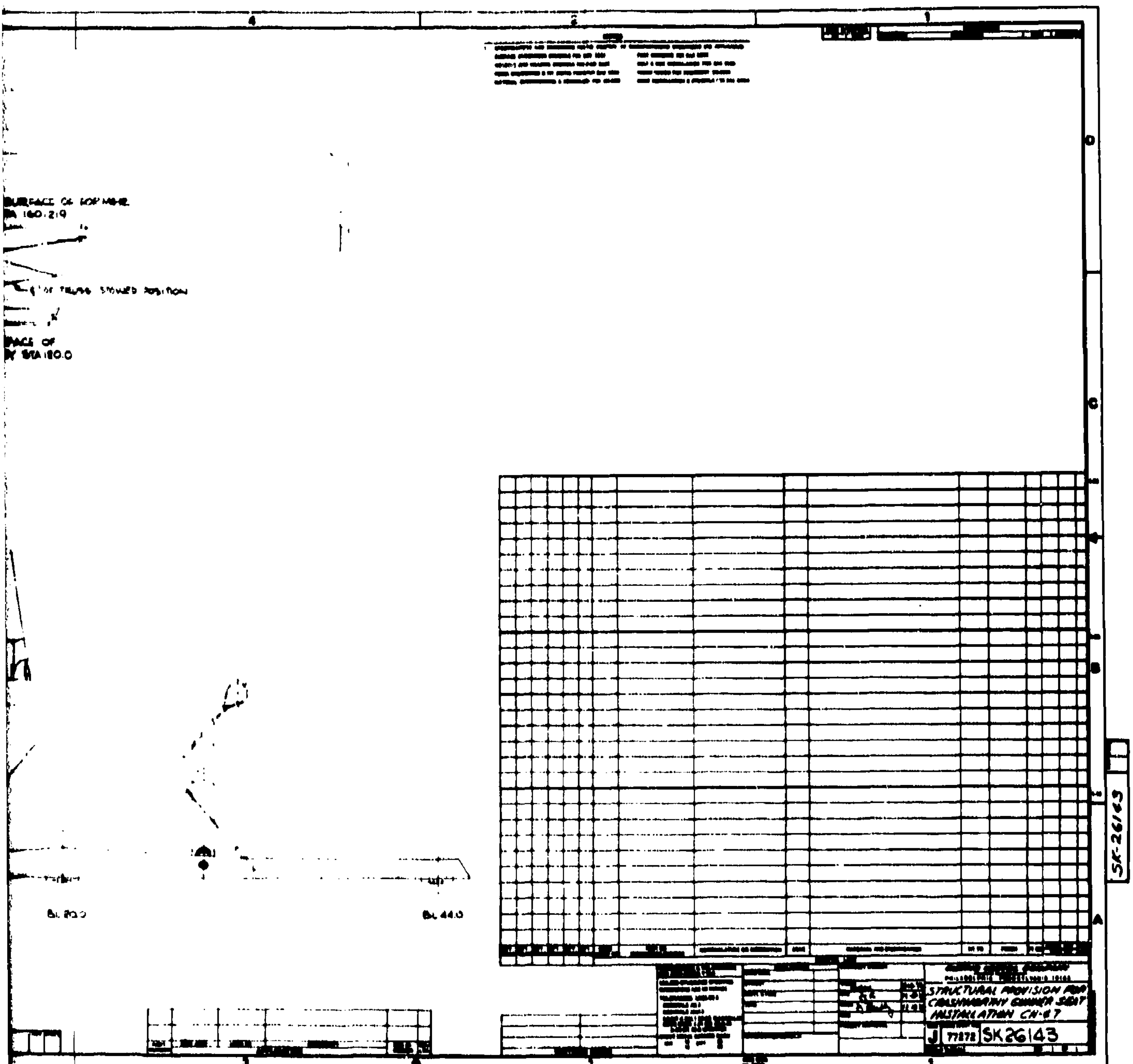

POINT 'C'
POINT 'A'
SECTION J-J
POINTS A & B
POINTS 'A' & 'B'
POINTS 'C' & 'D'
SEAT SUPPORT TRUSS STOWED POSITION
STOWED POSITION
SEAT SUPPORT TRUSS OPERATING POSITION
AN4-26A
AN960-416
MS21085-N4
SECTION B-B
STA 160.219
SEAT (BL 140.0)(REF)
SECTION G-G
SECTION E-E
SECTION D-D
STA 120.0
VIEW LOOKING INBD
WL 160.0
SK-26143

B


SECTION J-J
POINT 'A'
POINTS 'A' & 'B'
POINT 'A'
POINT 'B'
6.75
6.75
BOTTOM SURFACE OF FORMER ASSY STA 160.219
℄ OF TRUSS STOWED POSITION
POINT 'C'
POINT 'D'
BOTTOM SURFACE OF FORMER ASSY STA 120.0
STOWED POSITION
SEAT SUPPORT TRUSS OPERATING POSITION
8.63
8.63
℄ AIRCRAFT SYMMETRY
STA 160.219
WL 29.990
BL 12.50
BL 16.00
BL 12.50
BL 20.0
BL 44.0
VIEW LOOKING FWD
WL 29.990
BL 20.0
SK 26143

C



STA 160.219
℄ OF TRUSS STOWED POSITION
FACE OF
STA 120.0
BL 20.0
BL 44.0
STRUCTURAL PROVISION FOR
CRASHWORTHY GUNNER SEAT
INSTALLATION CH-47
J 77272 SK26143
SK-26143